A MANUAL

OF

GREEN MANURING

Prepared by the Department of Agriculture,
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PREFACE

Agriculture has in various countries and at various times attempted to solve the problem of obtaining cheap nitrogen. At the time that she has done it she has not always understood what actually was her quest, nor the way in which she was making it. She early obtained the empirical result that after certain crops some grew better than after others. The custom of growing leguminous crops, that is those with a legume, or pod, as their form of fruit, with the knowledge that those that followed them did well, undoubtedly existed long ages ago. It was a practice before the time when Jacob fed Esau on a sod potage of red lentils grown in the fields of Gerar. Sir Richard Weston about 1645 introduced to England from Flanders the growing of clover which eventually replaced the necessity to allow the land to lie fallow for long periods in order to recuperate from a state of nitrogen exhaustion due to continous cropping with cereals. It introduced the leguminous crop into a system of rotation and supplied the land with nitrogen obtained from the air. The value of this system was enhanced because its introduction was accompanied by that of turnips. The two together effected a change of the first order in English agriculture. It was at a time too when the latter was in a very degraded condition. This system laid the way for mixed farming in which livestock played their part with crops in a method of returning nitrogenous substance to the soil. Such a system made possible the utilisation of the straw of the cereal crops which previously was of little worth after its head of corn had been removed in the field leaving the stalk, or haulm, standing. The haulm which previously was only used in a common agricultural practice of burning the soil, or for thatching, now became trampled beneath the feet of cattle fed upon the clover and turnips and went eventually again on to the land in the form of a most valuable fertiliser and influence upon soil texture. Today it all seems such a commonplace procedure, but this application of science to agriculture effected in England a rural revolution. In central India the growing of crops, without rotation and without manuring, for more than two thousand years, has reduced the land to a condition of minimum yield from which only the introduction of a method like Weston's can ever lift it. In the uplands of Ceylon it is not age-long farming, nor wrong methods, that have produced the need for soil revival. Although Ceylon is geologically an ancient land yet in large measure her upland soils have been but comparatively lately formed and are not yet reduced to a mass containing any large amount of nitrogenous and organic matters. We have not on our plantations in Ceylon the possibility of introducing either rotation of crops or mixed farming. Plantation crops are essentially perennial ones, occupying the soil for a number of years. The problem then is how to stay a system of continual nitrogen depletion by removal of produce from

the soil. For Ceylon soils the quest for the nitrogenous element is a comparatively recent one, and along lines the way of which is now understood. This was not the case in Weston's day, the value of clover as a soil renovator had been stumbled upon blindly as it were. It was not until 1888 that the German botanists, Hellriegel and Wilfarth, established the fact that leguminous plants were not entirely dependent on the soil for their nitrogenous food but somehow obtained it elsewhere. They pursued their observations further and found that these plants were able to make use of the atmospheric nitrogen contained in the soil and that the power to do this was associated with the peculiar pill-like tubercles found on the roots. The English botanist, Marshall Ward, showed these tubercles to be due to the infection of the root by bacterium-like organisms. About the same time the Dutch botanist, Beijerinck, who died on the first day of the present year, 1931, added further to our knowledge by isolating from the root-tubercles a bacterium which he named *Bacillus radicicola* and which is an organism fixing the atmospheric nitrogen in a compound form such that the leguminous host plant can use it as food. Thus the leguminous plants obtain nitrogen from the air which, if they be later buried in the earth, gives to the soil an addition of this element.

The leguminous crop can only be introduced into Ceylon plantation agriculture when interplanted, and not rotated, with the economic crop, sometimes as a shade crop, or, at other times, as a green cover crop. This must later, either wholly or partially, be turned into the soil. Such green manuring by interplanting is a modern practice which seemingly originated in Ceylon within the memory of some now amongst us. It would be interesting if its introduction were recorded as history before it becomes wrapt in obscurity. From the introduction of this practice much benefit has accrued to plantation agriculture throughout the East. The custom is but still in an evolutionary stage, however, for fresh varieties of leguminous plants and new methods of utilising them are continually being tried. The term "green manuring" implies the ploughing in or otherwise burying any green crop. If the crop be a non-leguminous one then burying where the crop grew returns to the soil the nitrogen that it had taken from it, whilst the burying of a leguminous crop under similar conditions adds to the soil also the nitrogen that it had captured from the air.

The chapters of this manual have been contributed by various writers upon aspects of green manuring that they have made their special study. Much information too has been obtained from the experience of those who have practised green manuring in Ceylon and who were good enough to supply it in reply to a questionnaire issued by the Department of Agriculture.

In view of the importance of the subject it is trusted that this manual may be of use to the producers of agricultural crops that admit of the practice of which it treats.

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Peradeniya, Ceylon,
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INTRODUCTION

GREEN manuring is an agricultural practice which dates back to ancient times, but it is only comparatively recently that a scientific study of the subject was begun. Simultaneously with the development of our knowledge of green manuring, the adoption of the practice extended. At the present time it is widely practised in both temperate and tropical agricultural countries, and particularly so in the latter. The reason for this is not far to seek. Green manuring offers so many advantages to both soil and crop and its effect on the latter are so markedly evident, that it was bound to become popular wherever these advantages were demonstrated. In Ceylon, green manuring, in the widest sense of the use of plants for conserving or increasing soil fertility directly or indirectly, has come to be recognised as an essential agricultural operation on tea and, to a lesser extent, on rubber plantations. Within the last few years progressive coconut estates in Ceylon have started systematic green manuring. As for paddy, the value of turning in green leafy material while puddling the fields is universally recognised, but the practice is not followed as extensively as it should be. The scientific study of green manuring has received, in recent years, a considerable amount of attention from the staff of the Department of Agriculture, Ceylon, and much useful information has been secured. The results of investigations on the subject have been published from time to time in the various publications of the Department, but as they have been of a desultory nature, it has been considered advantageous to collect and classify all the available information. In this section, the general principles of green manuring with special reference to the various investigations carried out to determine how these apply to Ceylon agricultural conditions will be dealt with, and suggestions will be made as to how the

Ceylon practices may be modified in order to secure the best results. The chemical data obtained on the composition of specific green manures is also included in this chapter. Reference will further be made to the results of work carried out by investigators in other countries when they have a direct bearing on Ceylon agricultural problems. The specific green manures suitable for the different Ceylon crops and their treatment will not be considered in this section but in those that follow. Where a practice more particularly adopted in one crop is considered suitable for other crops as well, its advantages and applicability to the latter will be discussed.

Before progressing further, it would be best to explain the sense in which the terms *green manure*, *green manuring*, and *cover crop* will be used in this paper.

DEFINITIONS

By *green manuring* is meant the practice of incorporating into the soil undecomposed plant material with the object of increasing soil fertility. The green material may be grown *in situ* or brought from outside. It is commonly believed that only leguminous plants are beneficial as green manures, but this is not the case. Non-leguminous leafy material can be used for green manuring provided it is brought from outside and not grown on the area which is to be green manured. Leguminous plants are of value as green manures because of the large amounts of gaseous nitrogen they fix in the soil through the nodules on their roots. Most of the nitrogen contained in leguminous plants comes from the atmosphere[31]. The presence of nodules on leguminous roots is always an indication of nitrogen-fixation. All leguminous plants are not however nitrogen fixers. Further, varieties which normally produce nodules on their roots may not do so under certain conditions. Either the soil may not contain the specific bacteria necessary for nodule development, or, it may be so acid that the organisms are destroyed, or, it may supply such large quantities of available nitrogen to the legumes at all stages of their growth, that the latter will assimilate the nitrogen supplied and not fix any of, or all, the nitrogen they require, which they would do if the soil were not so fertile. The nodules contain bacteria which carry on the work of nitrogen-fixation, the energy for the process being derived from the carbo-hydrate material supplied by the plant. The greater part of the available nitrogen formed in the nodules is transferred to the stems and leaves where it is converted into organic nitrogen, but

some of it is assimilated by the bacteria in the nodules or goes into the roots. When, therefore, leguminous plants that produce nodules on their roots are grown in a soil, they can be expected generally to increase the nitrogen content of the latter to a small extent. If they are turned into the soil large quantities of nitrogen and organic matter may be added to it. On the other hand, though non-leguminous plants may contain large amounts of nitrogen, they take all of it from the soil. When these crops are turned into the soil on which they are grown, no extra nitrogen is added, but the available nitrogen assimilated from the soil is merely returned to it in organic form. As the plant material decays in the soil, the organic nitrogen it contains is transformed into inorganic nitrogen and the cycle is thus completed.

The term *green manure* will be employed for any crop material whether leguminous or non-leguminous, which is used for green manuring, and this will include *cover crops*, leguminous or otherwise, which are planted for the purpose of protecting and covering the soil. A cover crop can be used as a green manure crop.

ADVANTAGES OF GREEN MANURES AND GREEN MANURING

The chief advantages to be gained from the growing of green manures and the practice of green manuring are:

(1) Increase in the organic matter, especially the humus contents, of soils.
(2) Increase in the nitrogen content of soils.
(3) Conservation of the soil and its fertility and the improvement of its physical condition.
(4) Economy in the cost of weeding.
(5) A source of fodder.
(6) Conservation of the soil moisture.

These may now be considered more fully.

(1). *Increase in the organic matter and humus contents of soils.*—By ploughing in green manures, valuable organic matter is added to the soil; on decomposition this forms humus. Tropical soils in general, and Ceylon soils in particular, are for the most part deficient in organic matter. This is, as Mohr [1] points out because "the moisture and temperature conditions of the tropics are more favourable for the organic matter decomposing micro-organisms of the soil than for the higher plants which

furnish the materials for these organisms to act upon, the organic matter being destroyed as rapidly as it is supplied by plants". In temperate regions where green manuring has been practised large gains in soil organic matter and nitrogen have been recorded (6). Recent work (2) carried out at Peradeniya has shown that, under the conditions of these experiments, the carbon and nitrogen contents of soils may be maintained, or even increased, by the use of green manures. Eden(3) has shown that soil from an estate which had liberal green manuring had a higher organic matter content than one which was not so liberally green manured. More recently still, the results of organic matter and nitrogen determinations on soils from the tea plots under *Indigofera endecaphylla* at the Experiment Station, Peradeniya, taken after a four years' growth of this cover, showed that there was a marked increase in the organic matter and nitrogen contents of the soils as a result of growing the cover. The average organic matter content of these plots was 3·73 per cent. in 1925, 4·56 per cent. in 1927 and 5·29 per cent. in 1929. Green manure crops give from 2 to 10 tons of green material per acre and the increase in humus will therefore be appreciable after a few years. Humus has many properties. Among others (1) it absorbs water and the mineral constituents of the soil and regulates the supply of these and of nitrogenous substances to plant roots. Reference will be made again to the soil moisture relationship of green manures; (2) it improves the texture or tilth of soils, breaking up heavy soils and binding together light soils, and rendering them better able to withstand drought. Its presence in the soil serves to diminish the resistance of the soil to tillage implements. This has been clearly demonstrated at Rothamsted(4) from trials with the dynamometer—an instrument for recording the draw-bar pull on tractors, etc; (3) it is directly and indirectly the main source of nitrogen in the soil; and (4) on it depends the activity and number of the micro-organisms which are responsible for all the organic changes taking place in the soil. Amongst these organisms are bacteria, whose chief function is to fix the free nitrogen of the soil, the energy required for so doing being derived from the organic matter of the soil. The carbon dioxide formed as a result of the various biological processes which organic matter undergoes in the soil makes available to the crop some portion of the mineral constituents of the soil.

(2). *Increase in the nitrogen content of soils.*– The amounts of nitrogen supplied to the soil by green manuring with leguminous crops grown *in situ* or with non-leguminous crops brought

from outside can be considerable. In the case of the former reckoning on an average crop of 4 tons of green material per acre per annum, containing on an average ·6 per cent of nitrogen, the amount of the latter added to the soil will be at least 50 lb. per acre. This is a conservative estimate as it does not take into account the amount of nitrogen contributed by the roots and nodules of a leguminous crop. An experiment at Rothamsted[5] showed that on a plot on which clover had been grown previously, in addition to the 150 lb. of nitrogen taken up by the succeeding crop of barley, the soil nitrogen was enriched to the extent of about 450 lb. per acre to a depth of nine inches. Pieters[6] cites numerous other instances of the value of leguminous crops for increasing the nitrogen content of soils. Recent work carried out at Peradeniya has indicated that by the growth of green manures the nitrogen contents of soils are maintained while those of the controls have shown an appreciable fall. Thus the average nitrogen contents of the green manure plots were ·107, ·102, and ·110 per cent in 1928, 1929, and 1930 respectively and those of the controls ·098, ·087, and ·084 per cent respectively. The composition of the different green manure crops commonly grown in Ceylon will be dealt with separately later. Not all the nitrogen present in green manures is directly available for crops. Experiments in temperate countries have shown that if the availability of nitrate of soda is reckoned as 100, that of green manures is about 65. Some of the remaining nitrogen is incorporated in the soil humus, some of it is lost as free nitrogen or ammonia, and the rest leached from the soil in the drainage water in the form of nitrates.

(3). *Conservation of the soil and its fertility and the improvement of its physical condition.*—If a green manure crop is a cover crop, it prevents the loss of valuable surface soil from hilly and undulating land caused by the heavy rainfall of the tropics. This is entirely borne out by the soil erosion experiment carried out at the Experiment Station, Peradeniya, the results of which are shown in table I below [14]. The experiment was designed to compare the erosion on a hill slope from unprotected land (the control), with land growing a cover crop of *Indigofera endecaphylla* and with land where *Clitoria cajanifolia* was used as a contour hedge for preventing erosion. The plots were each one-thirtieth of an acre in extent. The table shows the average losses of soil in pounds per acre from differently treated plots. The figures in brackets show the percentage loss as compared with that of the control.

Table I

	Control lb.	Growing *Indigofera* lb.	Growing *Clitoria* lb.
1926-1927	863·8	738·1	1055·7
	(100)	(85·4)	(122)
1927-1928	1810·9	1538·4	2069·6
	(100)	(84·9)	(114·3)
1928-1929	1733·1	732·35	1416·6
	(100)	(41·7)	(81·7)
1929-1930	1039·7	321·8	577·9
	(100)	(30·9)	(55·6)

It will be noted that the plots in which *Indigofera endecaphylla* is grown as a cover crop show the lowest losses of soil. *Clitoria cajanifolia* as a contour hedge for preventing erosion, it will be observed, is not nearly so effective as *Indigofera* as a cover crop in the prevention of erosion.

Cover crops also take up the plant-fertilising constituents contained in the surface layers of soil which would otherwise be leached out. By green manuring the surface soil is supplied in a quickly available form with plant-food constituents obtained by the green manure crop from the lower layers of soil and the sub-soil. A cover crop also protects the soil against the beating action of the rain and the excessive heat of the sun. This in the tropics is a matter of great importance. Tropical rains are so heavy that the soil surface is often "capped" and made impervious to water. As a result, excessive losses of moisture from the soil surface take place through capillary action when dry weather sets in. When rain subsequently falls on the capped surface, the greater part of it flows over, and is not absorbed by, the soil. Green manures keep the soil open by their root action and hence rainwater is absorbed much more readily on green manured soils, and the natural drainage too is much improved. The growth of green manures thus improves the aeration and drainage of the soil and the roots of the main crop are enabled to penetrate deeper into the sub-soil. This is particularly the case with tree green manures as "dadap" (*Erythrina lithosperma*) and *Gliricidia* in tea.

The results of investigation at Peradeniya during the last three years have indicated that in the case of tree green manures the shade afforded by them, where good, is an important factor in counterbalancing losses of soil moisture by transpiration from the leaves and from the soil surface by evaporation, provided the drought is not too prolonged (7).

(4). *Economy in weeding costs.*—Green manures reduce weeding costs, especially on new clearings. Cover crops when firmly established smother out weeds and as weeding is a heavy item on many tropical estates, greater economy can thus be effected in the cost of production.

(5). *A source of fodder.*—The leafy material of many green manure plants, especially of the cover varieties, affords a very useful fodder for cattle. This is a point of great importance in certain planting districts where pasture land is generally not available and cattle essential for the welfare of the plantation. Part of the green manures grown under the crop can be reserved for feeding cattle. A few of these cover crops are, however, poisonous to cattle, e.g., *Phaseolus lunatus*. Care must be taken to prevent the cattle from getting at such a crop.

(6). *The conservation of soil moisture.*—It has already been mentioned that by turning in green manures the humus formed will help in increasing the moisture content of the soil. Work at Peradeniya carried out since 1925 has indicated that, in the case of cover crops, more moisture is lost to a depth of 24 inches during periods of drought from soils under cover crops during the first two years of the growth of the covers than from bare soil, but that after this period the reverse is the case. This is due to the fact that in the early stages of the growth of the covers more moisture is lost from the soil through transpiration than is retained by the surface layer of decomposed organic matter or by the shade afforded. The reverse is the case once the cover is well established and a layer of organic matter has formed as a mulch on the surface [7, 8]. The shade effect of tree green manures in relation to soil moisture conservation has already been referred to. Directly connected with the question of moisture conservation is that of the time of lopping and burying in green manures. This will be dealt with later. In the case of bush green manures, it has been found that the lopping and forking into the soil of these crops will ensure an increased soil moisture retention; by allowing them to grow during periods of drought considerable losses through transpiration will result, the shade effect of these crops not being sufficiently effective to counteract the transpiration losses. With reference to the soil moisture problem of green manures, it has to be pointed out that work carried out in America has shown that where the rainfall is less than 20 inches, green manuring is impracticable and not to be recommended [6, 9]. The green manure crops take the

moisture reserved for the main crop and, when turned under, do not have sufficient moisture for decomposition. The air spaces thus created cause further losses of moisture by evaporation.

THE COMPOSITION OF GREEN MANURES

In view of the frequent enquiries made as to the chemical composition of the more extensively cultivated green manure crops, and in order to ascertain to what extent leguminous green manure crops are richer in nitrogenous constituents than non-leguminous crops used for green manuring, analyses of the more important species of these plants were made. These were published at various times in *The Tropical Agriculturist* (10, 11, 12, 13). A few typical analyses of leguminous and non-leguminous plants are quoted in table II below. Analyses were carried out in most cases on the leafy green material and tender stems. The analytical figures cannot however be regarded as absolute for all samples of the same species of green manure, for it is obvious that they will vary with the age of the plant at the time of sampling, the soil and climatic conditions under which it was grown, the season at which it was cut, the proportion of leaf to stem, etc. They however give a sufficiently accurate idea of the manurial values of these plants, and as such may be of use and interest to agriculturists.

With regard to the leguminous green manures an examination of table II shows that there is a fairly wide range of variation in the nitrogen and ash contents of the different green manures. The nitrogen per cent of the leafy material on dry matter at 100°C varies from 2·95 to 4·84 except in the case of *Mimosa pudica*, the common sensitive plant, which has only ·97 per cent of nitrogen. The ash contents vary from about 6 to 11 per cent. Of the individual ash constituents, the figures for lime are highest on the average; the potash contents are fair, while the phosphoric acid percentages are low for all green manures. The percentages of dry matter remain fairly constant in the case of all these leguminous plants. The table also illustrates the variation in composition of *Gliricidia* and dadap leaves and twigs, and tender stems and branches. As expected, the nitrogen and ash contents of the older branches are lower than those of the leaves and tender stems (12).

In the analyses of the leafy material of non-leguminous green manure plants, the nitrogen contents on dry matter vary from about 1 to 2·95 per cent. These figures are much lower,

Table II

Analyses of Green Manures

	Of green material							Of material after drying at 100°C					
	Moisture	Organic matter	Ash	Nitrogen	Lime	Potash	Phosphoric acid	Organic matter	Ash	Nitrogen	Lime	Potash	Phosphoric acid
	per cent.							per cent.					
Leguminous Green Manures													
Dolichos hosei (Vigna)	79·9	17·8	2·3	·71	·43	·39	·18	88·8	11·2	3·53	2·13	1·94	·93
Indigofera endecaphylla	74·7	22·1	3·2	·78	·90	·41	·12	87·3	12·7	3·09	3 55	1·61	·48
Clitoria cajanifolia	74·2	23·6	2·2	·79	·39	·30	·15	91·4	8·6	3·05	1·50	1·16	·59
Crotalaria striata	75·2	22·8	2·0	1·00	·40	·33	·09	94·0	6·0	4·07	1·60	1·33	·38
do anagyroides	72·8	25·4	1·8	1·32	·53	·38	·10	93·5	6·5	4·84	1·96	1·38	·37
Tephrosia candida (boga)	64·4	33·8	1·8	1·72	·66	·49	·18	95·0	5·0	4·84	1·84	1·37	·50
Desmodium triflorum	50·9	44·8	4·3	1·40	·53	·67	·16	91·3	8·7	2·84	1·08	1·36	·32
Centrosema pubescens	65·5	32·3	2·2	1·39	·60	·34	·08	93·6	6·4	3·96	1·74	·99	·24
Calapagonium mucunoides	74·7	22·5	2·8	1·10	·79	·46	·14	88·8	11·2	4·34	3·11	1·83	·55
Mimosa pudica	69·4	29·2	1·4	·30	·29	·42	·10	95·5	4·5	·97	·95	1·37	·32
Dadap (leaves and tender stems)	69 8	28·4	1·8	1·09	·58	·34	14	93·9	6·1	3·62	1·91	1·13	·46
do (older stems and branches)	70·3	28·6	1·1	·32	·25	·24	·07	96·4	3·6	1·08	·83	·92	·24
Gliricidia maculata (leaves and tender stems)	73·1	24·3	2·6	·79	·77	·37	·19	90·4	9·6	2·95	2·88	1·37	·71
do (older stems and branches)	71·8	27·3	·9	·39	·20	·19	·07	96·9	3·1	1·40	·72	·66	·25
Non-Leguminous Green Manures													
Oxalis latifolia (leaves and bulbs)	85·0	13·4	1·6	·36	·26	·34	·06	89·1	10·9	2·38	1·73	2·26	·40
Tethonia diversifolia (wild sunflower)	77·1	19·5	3·4	·67	·73	1·21	·16	85·4	14 6	2·93	3·34	·5·27	·68
Adathoda vasica	70·7	24·6	4·7	·81	·14	·93	·19	83·8	16·2	2·77	4·90	3·19	·65
Thespepsia populnea (Suriya, S.)	85·8	12·5	1·7	·32	·39	·39	·11	88·7	11·3	2·26	2·74	.2·75	·77
Croton lacciferus (Keppitiya, S.)	57·6	38·8	3·6	·80	·12	·38	·27	91·4	8·6	1·88	2 93	·91	·64
Micania scandens	85·7	13·1	1·2	·38	·10	·52	·05	91·5	8·5	2·64	·70	3·63	·39
Grevillea robusta (leaves)	50·9	45·9	3·2	·53	1·30	·42	·06	93·4	6·6	1·08	2·65	·85	12
Strychnos nux-vomica (Goda kaduru, S.)	—	—	—	—	—	—	—	92·3	7·7	2·38	2·61	1·26	·32

on the average, than those of the leguminous green manures. It will be observed that in all cases where the leafy material is from large trees and hence in greater quantity than from shrubby or creeping green manure plants, low nitrogen percentages are obtained. The shrubby or creeping varieties, e.g., *Tethonia diversifolia* and *Micania scandens*, have nitrogen contents comparing favourably with those of leguminous green manures. The ash contents of the non-leguminous green manures are generally higher than those of the leguminous varieties. The figures for potash and lime are higher, but the phosphoric acid contents are about the same.

A point of importance about leguminous green manure crops is the amount of green matter they yield. The absolute amounts of fertilising constituents contributed by them will depend on their analytical compositions as well as on their total yields. The yields of green material vary considerably for the different varieties of green manures. The weights of loppings of tree green manures vary from 8 to 14 tons of green material per acre per annum [13], of bush varieties like *Tephrosia candida* from about 10 to 12 tons per acre, and of the creeping varieties from 3 to 6 tons per acre. The quantities of fertilising material added to the soil in the form of green manures can therefore be very considerable.

In order to determine the variation in composition and decomposability of green manures with age and hence the optimum time for lopping green manure crops in order to obtain the largest yield of quickly decomposing material containing large quantities of fertilising constituents, an investigation was started at Peradeniya with tree and bush green manure crops. The results obtained are interesting. They indicate that as the green manure crop advances in age the total amount of green material it gives increases but the proportion of leaf to stem decreases. In the case of bush green manures, the proportion falls from 2 to 1 when the plant is about four months old to 1 to 2 when the crop flowers. In the case of tree green manures the proportion falls from 3 to 2 when the branches are four moths old, to 1 to 3 when they are nine months old. As the crop matures there is a steady fall in the percentages of nitrogen and ash of the leafy material. Of the constituents of the ash, phosphoric acid shows the maximum decrease, and lime the

minimum. The nitrogen percentage of the stem is about one-fourth to one-fifth that of the leafy material and the ash percentage about half that of the latter. The largest amounts of nitrogen and ash constituents in the leafy material are found about the time of flowering and this would therefore appear to be the best time for cutting green materials in the case of bush and creeper plants. This finding is confirmed by the work of other investigators with creeping leguminous crops [6]. The "decomposability" of the green material from these types of green manures, which Rege [15] has demonstrated is dependent on its pentosan/lignin ratio, falls as the crop advances in age from about 1:1 at four months to 1:2 at the time of flowering in the case of the stems only. The pentosan/lignin ratio falls much more rapidly in the case of the branches of tree green manures. The "decomposability" of green manures therefore decreases with age. Work at Peradeniya has shown that, under the climatic conditions obtaining at this place, the optimum times for lopping *Gliricidia* and dadap branches are when they are about three and five months old respectively.

THE DECOMPOSITION OF GREEN MANURES IN THE SOIL

Green Manuring Under Dry-land Conditions.—The important factors connected with the decomposition of green manures in the soil are the physical state of the latter, climatic conditions, the soil micro-organic population, and the composition of the plant. Provided there is sufficient moisture in the soil, the decomposition of green manures will take place almost immediately they are turned in. Work carried out both in Ceylon and India indicated that the optimum soil moisture content for decomposition was three-eighths to one-half of the saturation moisture content of the soil. The actual amount will vary with the type of soil, but for a medium loam it was found to be some 15 to 20 per cent of moisture on dry soil [17, 18]. If there is insufficient soil moisture the material will remain undecomposed. This is what happens in arid districts and even in districts with a good rainfall if green manuring is carried out during periods of drought. The best time for turning in green manures so as to effect speedy decomposition is towards the end of the rains, when dry weather alternates with showers. This was clearly indicated from an investigation carried out to determine the losses of nitrogen from green manures through drying on the

field [23]. The decomposition will be the more speedily effected the better aerated the soil is. This is directly due to the beneficial effect of aeration on the soil micro-organisms.

Green manures offer an available source of energy for the activities of a great many micro-organisms in the soil responsible for the decomposition. Among the latter are fungi and bacteria. The presence of different micro-organisms will also influence the speed and nature of the decomposition. Fungi are believed to play an important part in the decomposition of the cellulose of plant material, the final decomposition products formed being humus, organic acids, and carbon dioxide. Bacteria are chiefly responsible for the decomposition of the organic nitrogenous material of the tissue, nitrate nitrogen being the final product formed. Several species of bacteria help in the decomposition, some functioning at one and some at another stage of the process. So far as is known amino-acids are first formed. These undergo reduction to ammonia which in turn is converted by the soil carbon dioxide into ammonium carbonate. A bacterial species *Nitrosomonas* converts the ammonium carbonate into nitrite, and this is rapidly changed by *Nitrobacter*, another species of bacteria, into nitrate.

The composition of the plant material plays an important part in the decomposition. Young plants decompose quicker than mature plants and plant residues since the first contain the more readily-decomposing constituents, namely, sugar, pentosans and proteins in large amounts, while older plants contain more of the decomposition-resisting lignins and celluloses. If the plant material is too mature as in the case of the thick branches of dadap, *Gliricidia* and even boga, its decomposition in the soil will be very slow indeed. Further, not only will there not be any liberation of ammonia or nitrates in the soil as a result, such as occurs in the decomposition of leafy green manure material, but there may be an actual consumption by the soil micro-organisms of the inorganic nitrogen of the soil. It has been found that for the liberation of ammonia and nitrate from green material buried in the soil, its nitrogen content should not be less than two per cent. [22] Most green manure materials have nitrogen contents considerably higher than this minimum; hence their incorporation in the soil should result in the liberation of large amounts of available nitrogen. The whole subject of the chemical and biological principles underlying the decomposition of green manures in soil has been ably dealt with by Waksman [22, 31], to whose papers reference may be made for further details.

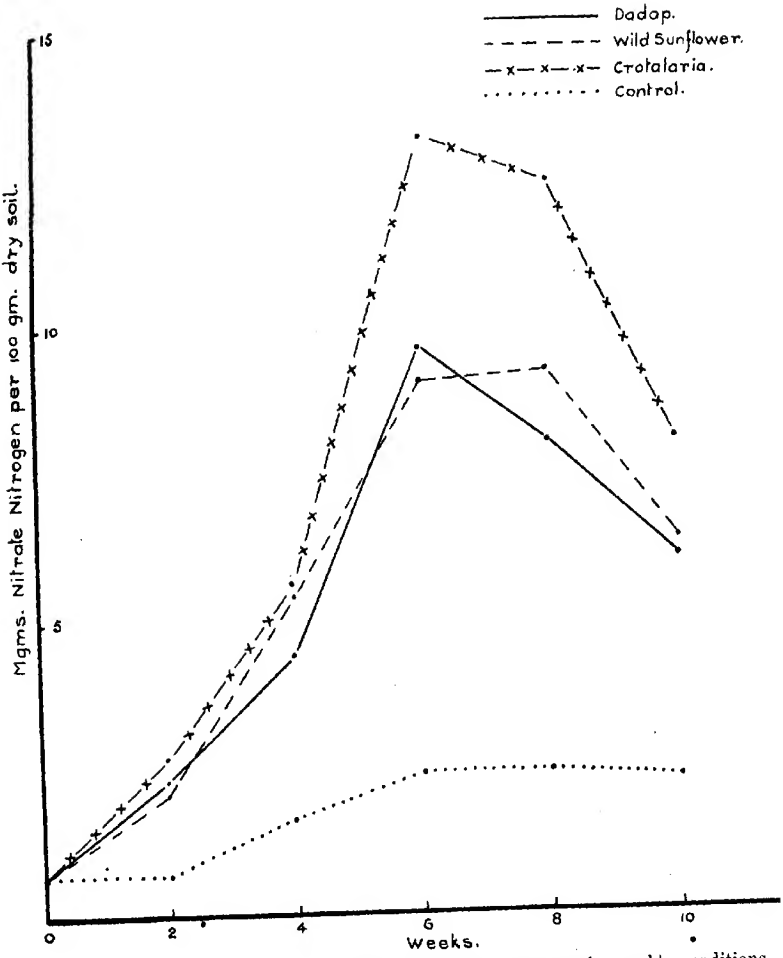

Figure I. Showing the decomposition of green manures under arable conditions in the laboratory.

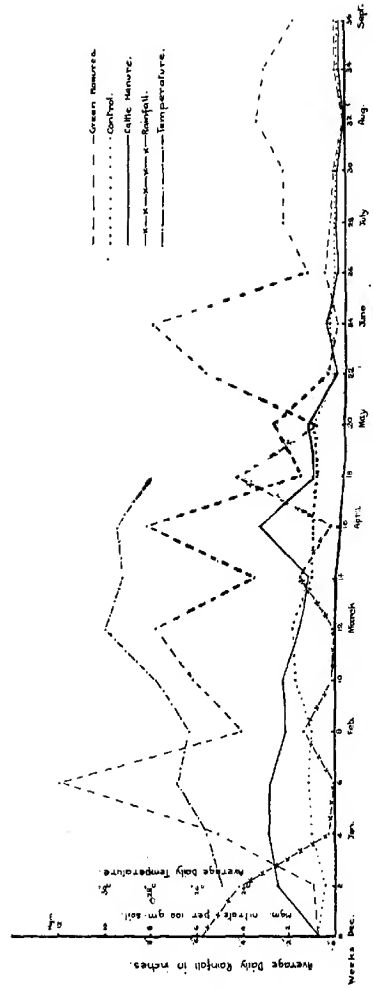

Figure II. Showing the decomposition of green manures under arable conditions in the field.

The results of both laboratory and field experiments carried out in Ceylon on the decomposition of the more widely-used green manures have been detailed in several papers in *The Tropical Agriculturist* [18, 19, 20], but it may be well to review briefly the general conclusions obtained. It has been shown that, (1) maximum nitrate accumulation or nitrification in the soil resulting from green manuring takes place between the sixth and eighth week after the burial of the green material. The field experiments further demonstrate that nitrification takes place subsequent to this, but to a lesser extent, and that after the fifth or sixth month the direct effects of green manuring from the nitrogen standpoint are hardly appreciable. Figures I and II will illustrate the above observations. Figure I shows the progress of the decomposition for some of the green manures in the laboratory experiments and Figure II the stages of the decomposition in the field. The curve for the nitrate content in the green-manured plots represents the averages for all the plots at the different times of sampling. The green manures used in these experiments were *Erythrina lithosperma* (dadap), *Gliricidia maculata*, *Tephrosia purpurea* (boga), *Albizzia*, *Crotalaria anagyroides* of the leguminous varieties and *Tethonia diversifolia* (wild sunflower) of the non-leguminous species. Cattle manure and control plots were included in the series. The full data of the laboratory and field experiments are shown in tables III and IV respectively.

Table III

Green Manure Laboratory Experiment Results

Treatment	Mgm. nitrate nitrogen per 100 gm dry soil						Maximum per cent. nitrified
	4/12/25	18/12/25	4/1/26	18/1	1/2	15/2	
Gliricidia	61	1·11	3·48	7·82	8·96	2·20	43·7
Albizzia	,,	·48	3·98	5·66	4·06	5·28	23·3
Dadap	,,	2·28	4·36	9·60	7·93	5·99	68·6
Wild sunflower	,,	2·07	5·44	9·06	9·12	6·31	67·2
Crotalaria	,,	2·60	5·34	13·20	12·40	8·20	77·7
Tephrosia	,,	3·23	5·09	14·40	14·20	8·19	60·0
Cattle manure	,,	1·54	1·76	2·48	3·17	2·22	27·5
Control	,,	·60	1·58	2·42	2·40	2.28	—

From what has been stated above it is apparent that under estate conditions it will be preferable to green manure at shorter intervals, e.g. at least twice a year and in smaller quantities than at longer intervals and with larger amounts of green material;

Table IV

Green Manure Field Experiment Results

Treatment	Moisture on green material per cent.	Nitrogen on material at 100°C per cent.	Mgm. nitrate and nitrite nitrogen per 100 gm dry soil														Maximum per cent. nitrified
			4/12/25	18/12/25	4/1/26	18/1	1/2	15/2	3/3	16/3	30/3	12/4	26/4	10/5	25/5	4/6	22/6	
Gliricidia	58·7	3·63	·63	·47	4·72	14·14	4·76	7·58	8·10	3·55	8·82	1·82	2·91	·95	—	·86	·67	86·3
Albizzia	56·4	3·19	,,	·56	4·96	10·40	4·10	4·43	4·67	1·93	8·65	1·55	3·18	·52	·48	1·37	·57	66·3
Dadap	76·2	4·39	,,	1·01	5·62	14·46	5·26	7·88	10·26	3·02	7·68	2·55	2·88	·53	—	·62	15	126·4
Wild sunflower	77·1	4·36	,,	2·06	4·55	11·69	4·87	4·77	7·43	1·94	7·62	1·47	2·22	·57	·46	·80	·78	105·0
Crotalaria	61·2	4·32	,,	·96	6·26	10·99	4·28	5·33	7·61	4·78	9·07	1·88	3·44	·95	—	·35	·80	70·5
Tephrosia	54·5	4·53	,,	·56	4·26	9·46	4·93	6·91	7·91	4·94	8·63	1·65	4·00	·43	—	·87	·66	40·2
Cattle manure	65·0	·81	,,	2·50	2·81	2·78	1·98	2·27	1·71	1·13	3·50	1·10	1·50	·30	·68	·29	·25	57·9
Control	—	—	,,	·41	1·00	1·19	1·00	1·74	1·81	·91	1·03	1·04	1·10	·37	·63	·19	·23	—
Green manures (Average)	*64·0*	*4·07*	*·63*	*·94*	*5·06*	*11·90*	*4·03*	*6·08*	*7·66*	*3·36*	*8·40*	*1·82*	*3·10*	*·66*	*·16*	*·81*	*·60*	---
Average daily rainfall during previous fortnight (inches)	—	—	·57	·41	·02	nil	·13	·03	nil	·16	·04	·45	·12	·60	·83	·16	·25	
Average daily soil temperature during previous fortnight (°C)	—	—	—	—	24·8	25·4	26·8	26·2	27·7	29·9	29·1	29·6	28·3	—	—	—	—	

(2) the amounts of nitrate present in the soil at any particular time in the green manure plots are dependent on the rainfall during the previous fortnight. As the rainfall increases the nitrate contents falls and vice versa. This is clearly seen in Figure II. The low nitrate content is probably due to (1) the washing away of the nitrate to the lower layers of soil, (2) excessive moisture which is detrimental to bacterial action. The temperature curve is noted to follow the nitrate curve; (3) the maximum nitrification percentages vary from 27·5 for cattle manure to 77·7 for *Crotalaria* in the laboratory experiment and from 40·2 for *Tephrosia* to 126·4 for dadap in the field experiment. The nitrification percentages are higher in all cases in the latter than in the former. This is probably due to the mineralisation of part of the organic matter of the soil, and the latter is certainly the cause of the high results obtained for dadap and wild sunflower in the field experiment. The great variation in the results is to be attributed to the variation in the composition and nature of the green materials used in the experiments; (4) the use of non-leguminous leafy material, e.g., wild sunflower, resulted in as great an accumulation of nitrate in the soil as when leguminous crops were used. The advantage of using such material for green manuring provided it is not grown on the field which is to be manured and provided it is cut before the flowering stage, is thus apparent; (5) the cattle manure plots show hardly any increase of nitrate over the controls. This is due to the low nitrogen content of the sample.

The addition of lime hastens the decomposition of green manures, as in the case of organic manures [20, 21, 22].

Experiments carried out at Peradeniya on the effect of desiccation on the nitrification of the leaves and tender stems of leguminous plants indicate that drying delays as well as hinders nitrification. A later investigation showed that dry weather alone does not encourage decomposition of green manure materials [23]. Other investigators too arrived at the above conclusions [24, 25]. The delay in decomposition is attributed to the conversion of soluble hemi-celluloses into less soluble forms as a result of the drying. From the above it will be realised how important it is that leafy material should be buried green and not dry in order to secure speedy decomposition.

In connection with the decomposition of green manures under arable conditions, it may be stated that experiments at Peradeniya have indicated that the effect of green manures here

is to make the soil somewhat less acid than what it originally was[2]. Work in other countries has shown that green manures do not materially, if at all, increase soil acidity in the field [6]

Green Manuring Under Anaerobic (Paddy-land) Conditions. In a paper such as this which deals with the general principles of green manuring in relation to all crops, reference should be made to investigational work carried out in Ceylon on green manuring under anaerobic (paddy-land) conditions. The practical aspect of this will be dealt with separately in the chapter on paddy and hence only the scientific aspect of green manuring under these conditions will be discussed in this chapter. The decomposition of green manures under anaerobic conditions such as obtain in swampy paddy land is brought about by soil micro-organisms. Harrison and Aiyer [28] showed that the gaseous products formed as a result of the decomposition of green manures under anaerobic conditions are carbon dioxide, hydrogen, marsh gas, and a small proportion of nitrogen. The main constituents of paddy soil gases are marsh gas and nitrogen. The former is oxidised to carbon dioxide by bacteria contained in the organized algal film on the soil surface. The carbon dioxide is in its turn decomposed with the evolution of oxygen, which becomes available for the aeration of the roots. The absence of carbon dioxide and hydrogen from paddy soil gases is attributed by Harrison to the reduction of the carbon dioxide by hydrogen as a result of a subsidiary bacterial action. Harrison and Aiyer attribute the efficiency of green manures upon paddy mainly to their indirect action on the soil by increasing root aeration, and not to the nitrogen contained in them, which they consider is liberated to a great extent as free nitrogen. The chief point of difference between the decomposition of green manures under dry land and wet land conditions, is that in the latter case ammonia and not nitrate is the nitrogenous end-product. Most previous workers [26] had shown that the rice plant took its nitrogen in the form of ammonia and hence the value of green manuring became apparent. A detailed investigation of the decomposition of green manures under these conditions in order to determine how green manuring of paddy could most effectively be carried out [26], has shown that as a result of incorporating green manures in paddy soils at the time of puddling, i.e., *late*, large quantities of ammonia are made available to the soil at all stages of the decomposition process and which coincide with the period of crop growth. Maximum

ammonification is obtained in about four weeks from the time of puddling. By *early* green manuring, i.e., ploughing in the green manures when the soil is semi-dry, large quantities of nitrates are formed. On the subsequent flooding and puddling of the soil these are lost as free nitrogen, leached in the drainage water, or reduced to nitrites which are injurious to paddy seedlings if present in excess. The amounts of ammonia found in *early* green-manured soils are very much less than those found in *late* green-manured soils. By the *late* green manuring of paddy soils their nitrogen contents can be maintained or even increased. *Early* green manuring results in large losses of soil nitrogen. No nitrates are found in paddy soils after they have been puddled, any nitrates present or added before puddling being denitrified or converted into nitrites. Large increases in crop

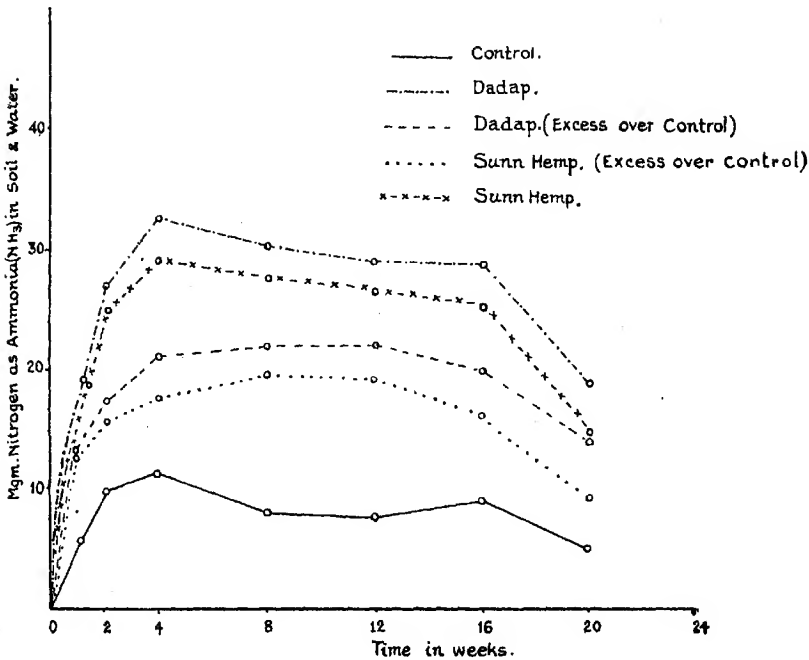

Figure III. Showing the decomposition of green manures applied *late* under anaerobic conditions in the laboratory.

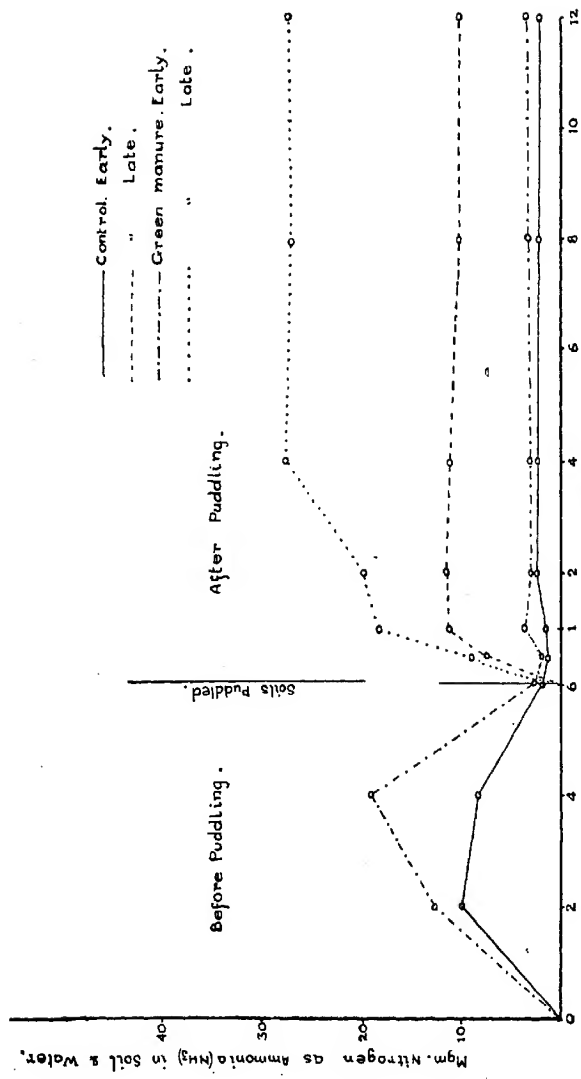

Figure IV. Showing the decomposition of green manures applied *early* under anaerobic conditions in the laboratory.

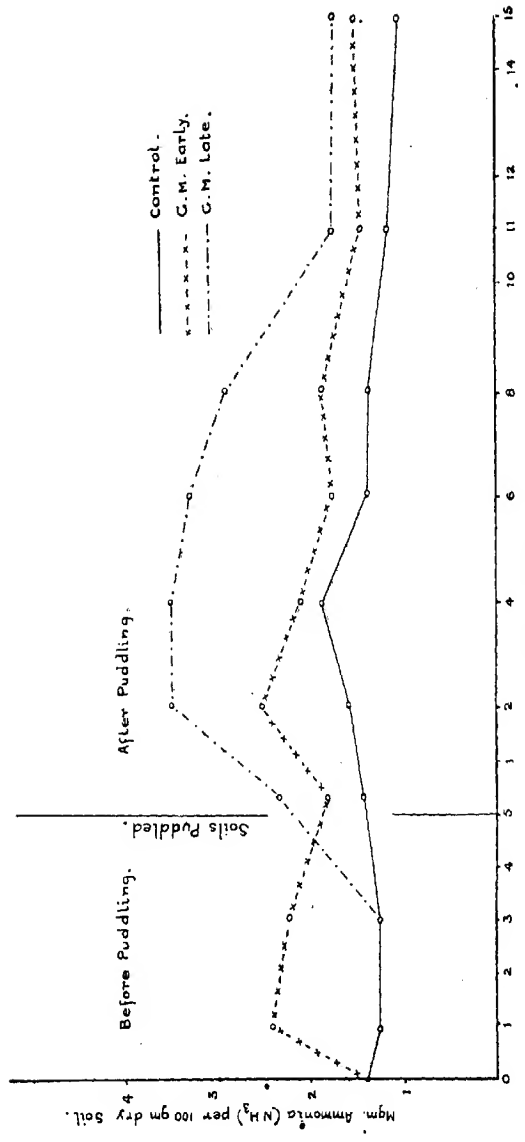

Figure V. Showing the decomposition of green manures under anaerobic conditions in the field.

yields of both grain and straw have been obtained through the *late* green manuring of paddy under anaerobic conditions [29]. Green manures can therefore be of direct manurial value to a crop like paddy if they are incorporated into the soil at the proper time.

Figures III, IV, and V will illustrate graphically the conclusions referred to in the above paragraphs.

CONSIDERATIONS ON GREEN MANURING PROBLEMS

(1). *On what soils should green manures be grown and under what climatic conditions ?*—Provided there is sufficient rainfall, green manures can be grown on any type of soil. Poor sandy soils in particular will benefit most by green manuring, as their humus and nitrogen contents and water-holding capacities will eventually be increased by the practice.

It has already been stated that where the annual precipitation is less than twenty inches, green manuring is not practicable; but very few parts of Ceylon are as dry as this, and most districts get the benefit of at least one monsoon. It is only in certain parts of the Northern and North-Central Provinces that green manuring would appear to be impracticable. In the Puttalam and Chilaw districts the soils are of a light sandy type, the rainfall on the whole is low, and long periods of drought occur. The question then arises whether green manuring can successfully be practised under these conditions. It is possible to do so, but under such conditions a quick-growing annual leguminous crop should be grown. It should be cut and left as a mulch during the drought and ploughed in during the next rainy season, a second crop being planted at the same time; or, where possible, the green manure should be forked in early enough for decomposition to set in before the rains cease. In districts with adequate rainfall green manuring will offer all the advantages already referred to.

(2). *The optimum time for cutting and the best method of treatment of green manures.*—Green manures should be cut at a stage when (1) they produce the maximum quantity of easily-decomposable green material, (2) climatic considerations demand that they should not compete with the main crop for the moisture in the soil. On the first point it has already been stated that in general the optimum time for cutting green manures for forking into the soil is just about the time of flowering. This applies to the bush and cover types in particular. The tree types are best lopped when the branches are from three to four months old.

The loppings or cuttings of all green manures, particularly in drier districts, should be ploughed in towards the end of the rains when showers alternate with dry weather. If ploughing is not possible the green material should be left as a mulch on the surface. In this case a certain amount of the carbon and nitrogen of the green material will be lost, as was found at Peradeniya[23] but as in these dry districts moisture is the limiting factor of crop growth, the mulch will serve as a useful means of conserving soil moisture. It is preferable, however, to turn in the cuttings about three to four weeks before the drought sets in, as by that time a certain amount of decomposition will have taken place and the decomposed material will have been able to retain some moisture for the subsequent use of the crop. In wet districts or in districts with an evenly distributed rainfall it is preferable that green manures should be turned into the soil immediately. The reason for this is that the drying of green manures delays as well as hinders nitrification, and loppings left on the surface are completely dried in a short time if dry weather prevails. If dry weather should alternate with wet weather then large losses of nitrogen and organic matter may result [23]. Thus losses of over 43 per cent of the nitrogen of *Gliricidia* and 37 per cent of dadap leaves were found at Peradeniya, when alternate dry and wet weather occurred. When dry weather alone prevailed, decomposition of the leafy materials did not take place and no losses of nitrogen consequently occurred. The loss of nitrogen is also effected by the nature of the plant material and this is greater in the case of more easily-decomposed leaves such as *Gliricidia* than tea and *Grevillea* leaves. The forking in of green manures in the fresh state is therefore advocated whenever possible. On no condition should green manures be cut and forked into the soil during a drought, even at the beginning of it. This applies particularly to light sandy soils in dry districts where green manures are ploughed in. It may be necessary in some instances to compact the soil after green manuring in order to minimise losses of soil moisture and to establish capillarity in the soil. The loppings of tree and bush green manures should not be allowed to become too woody. If in this conditoin, they should not be ploughed into the soil.

(3). *How can a good growth of green manures be obtained on poor soils* ?—It may be found difficult to establish green manures for the first time both on medium and on poor soils. In this case the following methods may be tried:

(i) *Manuring the crop.*—The green manure should be given a start by applying cattle manure to the seed bed. If this is not available, some nitrogenous manure, e.g., a mixture of nitrate of soda and blood meal incorporated with twice its weight of soil should be supplied at the rate of a handful or two per hole. Leguminous crops will be benefited by the presence of nitrogen in the early stages of their growth till the formation of nodules has taken place. Potash and phosphoric acid should also be applied as the green manures have to compete with the main crops for these fertilising constituents. As a result of manuring, the nodule bacteria are reported to become more active and able to enter the plants readily, and nodule formation is increased[6]. The root growth of leguminous plants in general is stimulated by manuring with phosphatic acid.

(ii) *Inoculation.*—Leguminous crops at times do not come up well in new areas. This is because the soil does not contain the specific type of bacteria needed by the particular legume for the formation of the root nodules. In this case inoculation of the soil or of the seed becomes necessary. There are three methods of soil inoculation, of which the soil method is alone suitable under Ceylon conditions at the present time. It consists of broadcasting over the area to be planted 300-400 lb. of soil per acre which has been taken from an area on which the green manure, it is desired to establish, has been grown with success.

(4). *Other practical points on green manuring.*—As regards the period of retention of green manures it may be stated that, in general, perennial cover crops should not be allowed to grow for more than two or three years without being ploughed in. The reasons for this are that the soils on which these covers grow (1) need periodical cultivation and aeration, (2) get "sick" as the result of growing one particular crop. For the latter reason it is advisable to have a rotation of green manure crops. Bush green manures depending on the particular species will need replanting once in two to four years. Tree green manures can be left to grow for several years, but they should be rooted out if attacked by disease.

Cover crops should be ploughed under in alternate rows across the slope of the land once every year or so. Where the green manure crop is a heavy one, it should be cut up with a disc-harrow or rolled before ploughing in. Bush green manures should preferably be planted in contour belts. When planting out green manures for the first time a heavier seed rate than is

normally required, especially if seed is plentiful and comparatively cheap, is recommended. By this means a cover will be more quickly established and weeds more effectively suppressed. Generally speaking it is preferable to plant green manure seed in rows. A mixture of seed generally gives better results than seed of one variety. The seed bed should receive careful preparation. Planting should be carried out at the beginning of the rains and weeding should be done in the early stages in order to give the green manures a start.

When using a green manure as the main source of nitrogen, the inclusion of an organic manure such as groundnut cake or blood meal in the artificial mixture is not recommended; but the application of a small quantity of a concentrated nitrogenous fertiliser such as cyanamide along with the green manure is advised. The reason for this is that as the carbon/nitrogen ratio of the soil has been found to remain constant at about 10 to 1 [(2)], and as green manures have a much higher carbon/nitrogen ratio, some concentrated nitrogenous fertiliser would appear necessary if a permanent improvement in the nitrogen content of the soil is to be effected. Further, only about half the nitrogen contained in green manures is available in a short time. It is also advisable to plough in some cattle manure along with the green manure as the large number of bacteria present in the former will hasten the decomposition of the latter.

(5). *Some limiting factors in green manuring.*—As with all other farm practices, green manuring has its limitations, and these are governed by crop and climatic conditions, cost of seed and of application, insect pests and fungus diseases of both the green manure crop and the main crop, and inadequate monetary returns [(6)]. Climatic conditions essential for green manuring have already been dealt with. As regards crop conditions it is known that some green manures will not grow under the heavy shade of the main crop, such as rubber, others in the open, as in young clearings. Again, certain green manures of the tree type will be unsuitable for young plantations. Others again have a climbing tendency and, therefore, should not generally be grown in new plantations, or if they are, they should be kept away from the young plants. In Ceylon, suitable green manures for all crops under all conditions are available and there is no crop which will not benefit by green manuring, judiciously carried out. The cost of seed is a factor of importance at the start. Once green manuring has been adopted, however, this difficulty may be overcome as seed becomes available. The initial expenditure

on green manuring may be fairly high, but this will more than be compensated for by a saving on the fertilisers purchased. Seed of all kinds can be obtained comparatively easily and cheaply in Ceylon. Though the cost of application, in which is included the cost of cutting and forking in, if the latter is carried out, will be found to vary in the different districts, it is not prohibitive.

The question of fungus diseases and insect pests both of the green manure crop and of the main crop in which they are grown in Ceylon will be dealt with in separate chapters.

Green manuring will not be an economic proposition if adequate monetary returns are not secured. The nett result should not be measured by the returns of produce obtained after one or two years, because the residual and cumulative effects of green manuring are considerable, and apart from directly benefiting the crop, soil conditions will also be greatly improved. As far as the main Ceylon crops are concerned, the satisfactory returns obtained by the judicious use of green manures in tea, cocoa, and paddy cultivation are recognised. Evidence to prove that green manuring benefits rubber and coconuts is also being obtained, and the practice with reference to these crops will be considered in detail in the chapters to follow.

(6). *Green manuring practices on Ceylon estates, and suggestions for their improvement where desirable.*—It may be well briefly to outline some of the practices followed by estates, and to indicate in which ways, if any, they may advantageously be modified. Tree green manures, e.g., dadap and *Gliricidia*, are lopped on nearly all estates from once to two or three times a year, and even more often. More frequent lopping is certainly preferable for the reasons that firstly a greater amount of easily decomposable green material and much less decomposable woody material is obtained and secondly, as the direct effects of green manures do not last for more than five or six months under Ceylon conditions, a continuous supply of nitrate nitrogen will be available to the plant if lopping is frequently carried out. On one estate as many as six loppings are done, the method adopted being to slash the green manure trees across as is now done to tea in the low-country. The loppings are left as a mulch on the surface either across the slope of the land or down the rows of the crop. Some estates envelope-fork all loppings into the soil each time the trees are lopped either in every row or in alternate rows. Others fork in the loppings from certain cuttings

only, e.g., along with artificial manures; at other times the loppings are left as a surface mulch. Others again fork in the leaves and more tender branches only, the more woody branches being used either for supplying vacancies or as firewood. Many estates use the tender leaves and stems for filling into supply holes. The loppings are either cut into small pieces or left as they are; or again, they are buried in deep trenches or holes between the rows of the main crop. Whenever this is done a layer of soil should be placed over a layer of the green material. The practice of burying in trenches is not one to be generally recommended, as it is likely that only the trees or bushes immediately adjacent to the trenches would profit most by it. Loppings may however be buried in large shallow trenches between the rows of the main crop as in the case of coconuts. The practice of forking in the loppings above each bush has distinct merits. Some estates plant out green manures on the manured areas between the rows of the main crop, e.g., coconuts. This is a mistake, for as pointed out already, if a leguminous crop is given a source of available nitrogen it will make no effort to obtain the nitrogen it requires for its use from the air. Further, the green manure crop will even temporarily compete with the main crop for some of the other available fertilising constituents contained in the manure mixture applied. Green manures should in these cases be grown in the unmanured areas.

Whenever it is possible and economical for green material to be turned into the soil, especially in districts with adequate rainfall where dry weather alternates with rain, this should be done. The woody portions of the loppings should not be forked in, but preferably left on the surface of the soil across the slope of the land, used for filling in vacancies or where either of these practices is not convenient or advisable, burnt and the ashes forked in. The reasons for not burying the woody loppings are that they take a very long time to decompose in the soil owing to their high lignin and low pentosan contents; secondly that they contain only very small amounts of nitrogen, so that in the process of decomposition the bacteria responsible for bringing it about will utilise some of the available soil nitrogen required by the crop and thus cause a temporary setback to the latter; and finally because of the danger of pests and diseases. If the green material is not turned in, a large percentage of the nitrogen and organic matter it contains may be lost [23]. The best practice would be to fork in the leaves and tender stems either along with artificial manures or alone during periods of light rainfall. The

loppings cut at the beginning of a period of drought may be left on the surface as a mulch, especially in dry districts, and the leafy material later forked in, if necessary. It need hardly be stated that tree green manures should not be left unlopped and the more frequent the loppings the better. Big trees like *Grevillea* and *Albizzia* are generally not lopped, the natural leaf fall affording sufficient organic material for forking in.

Bush green manures as boga and *Crotalaria* should be treated in the same way as the tree types.

The practices governing the use of cover crops vary a great deal and more experience with these needs to be obtained. Some estates leave the cover untouched for two years or more, except perhaps when manures are being supplied; others envelope-fork the covers perodically depending on the growth and nature of the cover. In some cases the cover is cut and artificial fertilisers may or may not be added at the time of forking in. In other cases the cover crop is cut and buried in trenches. Others again cut and envelope-fork in the green manure in alternate lines. The best practice would be to fork in alternate contour bands of the cover crop every year. This may not be convenient in the case of all crops, but it can always be adopted in some modified form. By so doing the cover acts as an effective soil conserver and also adds to its fertility.

SUMMARY

In the preceding pages an account has been given of the necessity for, the importance of, and the advantages of green manuring in tropical countries generally and in Ceylon in particular. It has been indicated that by the judicious use of green manures, which term includes cover crops, the nitrogen and carbon contents of the soil can be maintained, its physical condition improved, its moisture-retaining capacity enhanced and erosion effectively prevented. The analytical composition of certain plants, leguminous as well as non-leguminous, used in Ceylon for green manuring is tabulated and compared, and the conditions under which either class may be used as green manures explained. The results of investigations on the variation of composition with age are also briefly summarised. The principles underlying the decomposition of green manures in soils under both aerobic and anaerobic conditions are then discussed, and the results of experimental work on the subject in Ceylon are outlined. The chapter concludes with discussions

on certain practical green manuring problems, viz., soil and climatic conditions suitable for the growth of green manures, the optimum time for cutting and forking in green manures, measures to be adopted for securing good growth of green manures, some of the limitations of green manuring, and green manuring practices on Ceylon estates and the respects, if any, in which they may be advantageously modified.

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SECTION II

THE GREEN MANURING OF TEA, COFFEE, AND CACAO

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TEA

THE use of leguminous and other plants in tea is widespread in most countries where tea is grown. The general principles involved in the use of such plants have been discussed in Section I. For a more detailed examination of the practices followed consideration of these plants under the headings trees, bush plants, and creepers can be conveniently employed.

TREES

The advantages to be gained by planting trees among tea are as follows:

(1) Shade is provided for the crop and the soil.

(2) Some shelter from the wind is afforded.

(3) The roots of the tree help to open up the soil and may assist drainage.

(4) If leguminous trees are used the other advantages enumerated can be obtained without greatly depleting the store of nitrogen in the soil and an increase of nitrogen may even result.

(5) The direct impact of rain on the soil is to some extent broken and this, coupled with the effect of the leaf fall or loppings left on the surface, helps in checking soil erosion.

(6) There is evidence to show that high shade is beneficial in lessening tortrix attack.

(7) Natural leaf fall or loppings left on the surface of the soil form a mulch which helps to preserve soil moisture in dry weather. In addition such material will gradually decompose and will eventually augment the humus content of the soil.

(8) Loppings incorporated into the soil by forking or burying will make a valuable addition to the humus content of the soil and such green material provides nitrogen in a cheap form.

(9) The shade provided by the trees helps to check weed growth.

(10) In young tea clearings food, which might otherwise have been lost owing to the small area occupied by the roots of the young tea plants, is taken up by the trees and later returned to the soil in the form of leaf-fall or loppings.

(11) The planting of trees may increase the rainfall, or check the diminution of the rainfall caused by clearing jungle.

(12) The planting of trees may encourage birds which prey on insect pests.

The predominance of any one of these advantages will depend on the conditions in each case. It will often be impossible to say in which way the chief benefit is obtained.

Each of these points will now be discussed in detail.

(1) *Shade.*—The shading of the soil and of the tea must be considered separately. It is generally accepted that the constant exposure of soil to tropical sun results in loss of humus and consequent deterioration in fertility. There may be occasions where in very damp districts too heavy a shading of the soil would be detrimental. In this case, as will be mentioned later, the tea would also be directly detrimentally affected, so that on a well-managed estate such conditions are not likely to be allowed to develop.

The question as to whether tea actually requires or is benefited by shade has been frequently discussed. A good deal probably depends on the elevation and climatic conditions.

Elliott and Whitehead [13] write "In the low-country and mid-country the planting of trees is also done with a view to providing shade for the tea". Hope [20], writing of North India, says "slight shade is probably of direct benefit to tea" and points out that after a certain point light retards the growth of plants. He also points out that tea in its natural habit is a jungle plant and is not accustomed to fierce light.

Hope and Tunstall [21] say "It is generally believed that the tea plant thrives best under light shade but it has also been proved that too much shade retards the growth and renders the plant liable to all manners of ailments".

Mann and Hutchinson [28] believe that in northern India the slight shade given by *Albizzia stipulata* is beneficial in certain positions such as a hot south or south-west slope on the plains: they qualify their statement however by saying that it is extremely probable that the beneficial effects attributed to the actual casting of shadow are in reality obtained in other ways.

There is a fairly general opinion that low-country tea in Ceylon requires shade, though again this assertion is often qualified by the admission that shade is probably not the most important factor involved. It is also often stated that the mid-country tea requires shade. There are plots of perfectly healthy tea growing at Peradeniya without shade but there is also ample evidence of the value of planting leguminous plants in tea. If the value of planting trees in tea is generally admitted the question of whether the actual casting of shadow is beneficial or not rather loses importance since even if actual shade were proved to be of no importance the practice would still prevail.

There is one aspect of the question which deserves attention. Several superintendents, particularly in Uva, state that tea suffers much less in drought if shade is provided. The reason for this is not perfectly clear. Theoretically the presence of trees in full leaf should result in a greater loss of moisture through transpiration than is saved by shading the ground and checking surface evaporation and the proper course would be to lop the trees at the beginning of the drought, thus simultaneously reducing loss by transpiration and providing a mulch of leaves on the surface which would materially assist in checking evaporation. Joachim and Kandiah [23] have studied this subject during drought at Peradeniya. In the experiment of which they write there is no mulching of leaves done but the comparison between plots with unlopped green manure trees and bare control plots is of interest. The authors found that in the early stages of drought plots containing unlopped *Gliricidia* contained more moisture at all depths than the bare control plots, but in the later stages of the drought the moisture content in the bare control plots was very slightly greater than that of the plots containing unlopped *Gliricidia*. The droughts sustained in Uva are of long duration and one would expect a progressive loss of soil moisture to the final detriment of the tea in fields bearing shade in full leaf. The opinion however that tea weathers a drought best under shade is widely held and emphatically expressed.

Whatever ambiguity there may be over the question of the necessity for shade for tea there is none concerning the effect of too dense a shade, Mann and Hutchinson [28] state that too much shade tends to increase the amount of stalk. This view is generally brone out by Ceylon planters. Overshaded tea has usually a healthy colour, but the crop is short, the leaf is stalky, and the quality of the made tea is poor.

(2) *Shelter from Wind.*—If trees are planted with the sole or principal object of breaking the force of the wind they are usually planted in close belts running roughly at right angles to the prevailing wind. Such a practice is really outside the scope of this treatise but as trees planted in belts as windbreaks benefit the tea to some extent in other ways, a brief mention will be made of the practice. Probably *Grevillea robusta* and *Acacia decurrens* are used for windbelts more than any other trees. Both these trees afford a heavy litter of fallen leaves and if they are planted in belts along the boundaries or in the tea a good deal of this litter will be scattered over a wider area than that actually occupied by the belt. The subject will be mentioned again in the notes on individual trees.

Trees spaced throughout the tea, however, will do much to protect the tea from the full force of the wind and in some windswept districts this may even be the principal object in planting trees. In such cases the ability to stand up to wind is the most important consideration in the choice of a tree.

The superintendent of an estate in Bogawantalawa writes that at 5,200 feet he plants *Acacia decurrens* because other shade trees will not stand up to the wind. The superintendent of an estate in Haputale testifies to the value of the dadaps in a windy district, but this is not generally borne out and the writer has seen on a very windy slope dadaps almost leafless and affording very little protection to the tea. In the case in question the superintendent was making use of a species of *Eugenia*, known locally as Wal-jambu, for planting in the most windswept portions of his estate. These trees stood the conditions well and afforded a considerable measure of protection.

Mr. F. A. Stockdale, commenting on the question, wrote "I have for some time considered that a breakaway from tradition in regard to windswept areas in Ceylon was very essential and this I attempted to make clear in a note to the Morawak Korale Planters' Association. I personally think that windbelts of mango—the common type—may well be worth while. This is commonly used, with an indigenous *Calophyllum*, in Grenada in the West Indies in windswept cacao in hilly areas".

"Definite windbelts appear to be desirable but what trees can be used has yet to be definitely ascertained. *Eucalyptus* and *Grevillea* suggest themselves, but neither of these will grow satisfactorily on heavy soils where drainage is inferior. For windbreaks it is not necessary to confine the choice to leguminous trees and it is quite possible that in badly blown areas breaks of mango, del, jak, domba, jambu or Malay apple could be grown with material advantage. Experiments with various plants should be made. It is unnecessary to indicate the checking effect on the growth of tea that an uncontrolled full sweep of high wind will have."

Mr. Stockdale's remarks deserve the most serious consideration. Where a tree of proved value to tea will in other ways stand up to wind and effectively check its force its use is indicated. Examples are to be found in the use of *Acacia decurrens* at elevations between 5,000 and 7,000 feet and of *Grevillea robusta* round Hakgala, Welimada and elsewhere. Where the commonly grown trees will not serve the purpose fresh species should be tried.

The well-known incompatibility of tea and *Eucalyptus* precludes the planting of the latter actually among tea. There may be cases in which belts of tea seed bearers might be made use of but in that case conditions would not be favourable for the production of tea seed.

Where trees are planted primarily or largely for protection against wind lopping will have to be done some time before the windy season so that the trees carry as much foliage as possible when the wind comes.

(3) *Root Action.*—There is a considerable body of opinion in favour of the theory that root action is one of the principal ways in which benefit is obtained from planting trees in tea.

It is probable that in Ceylon this action is best exemplified in the case of *Albizzia moluccana.*

Speaking of *Albizzia stipulata* in India, Mann and Hutchinson [28] point out that the root action of this tree is most important; not only do the fine rootlets effect a most efficient cultivation of the soil but a considerable improvement to drainage is effected. In this way the root range of the tea bush is considerably increased. To show the enormous range of the roots of these trees the authors quote measurements taken on an estate. These figures are given below:

Age from planting	Height of trees	Radius of root range
1 year	$6\frac{3}{4}$ feet	8 feet
2 years	14 ,,	17 ,,
3 ,,	16 ,,	27 ,,
4 ,,	17 ,,	33 ,,
5 ,,	20 ,,	55 ,,

Further records are quoted of comparative leaf obtained from bushes near *Albizzia stipulata* and those far away from them.

Position of bushes	Weight of leaf from 100 bushes	Weight of leaf per bush
1. Near *Albizzia* trees	180 lb.	1·8 lb
2. ,, ,, ,,	$160\frac{1}{2}$,,	1·6 ,,
3. ,, ,, ,,	$180\frac{1}{2}$,,	1·8 ,,
4. Away from *Albizzia* trees	91 ,,	·9 ,,
5. ,, ,, ,,	70 ,,	·7 ,,

There is of course no positive proof that the benefit obviously obtained is actually or only due to root action and against this contention may be set the obvious detrimental effect on tea of the proximity of large rubber trees. This latter fact would rather point to the view that *Albizzia* being a leguminous tree the benefit is rather derived from its power of assimilating nitrogen. This is a question which cannot easily be solved but in Ceylon it is also frequently found that tea bushes growing close up against large *Albizzias* have a particularly vigorous appearance. As far as the writer is aware there are no Ceylon figures with regard to the relative yield of tea bushes growing near to, or far from, shade trees but several superintendents have testified to the value of the root action of shade trees, particularly *Albizzia*.

(4) *Nitrogen Assimilation.*—Leguminous plants usually form nodules on their roots in which are found bacteria capable of assimilating nitrogen from the soil atmosphere. This fact has been demonstrated by growing legumes in quartz sand wholly devoid of nitrogen, only the necessary bacteria and minerals being added. Under ordinary conditions, however, only a proportion of the nitrogen found in a leguminous plant is assimilated from the atmosphere, the remainder being taken from the soil in the ordinary way. Even so, if the entire plant were returned to the soil, an increase in the nitrogen content of the soil should reasonably be expected. This of course cannot be done with trees but a proportion of the leafy matter is usually returned to the soil. The proportion of the total nitrogen taken up which is assimilated from the atmosphere is stated to vary

with different leguminous plants, and further the ability to assimilate atmospheric nitrogen varies with different leguminous plants. The fertility of the soil also affects assimilation of nitrogen—in a poor soil the plant assimilates more nitrogen from the atmosphere and in a fertile soil less. There are also other causes of variation in the amount of atmospheric nitrogen assimilated.

Apart from the question of the return of the green material to the soil is the problem of whether the mere presence of a leguminous tree, showing nodule formation on its roots results in an increase in soil nitrogen. Evidence in this connection under tropical conditions has recently been collected by Joachim and Pandittesekere [24]. As has been pointed out in Section I the automatic preservation of a more or less fixed carbon-nitrogen ratio largely determines the amount of nitrogen to be found in a soil. In the Peradeniya experiment discussed by the authors a slight loss in nitrogen was found to have occurred in most plots planted with leguminous trees and bush plants. This was so whether the trees were lopped and the loppings forked in or whether they were left unlopped. A larger loss however occurred in the bare control plots and the authors infer that the presence of these leguminous plants has checked the natural loss of nitrogen which occurred on the bare plots, even though the latter were uncultivated.

There is therefore no assurance that the presence of leguminous trees will result in an actual increase of soil nitrogen but there is every probability that the nitrogen content of the soil will be higher than it would have been if no leguminous trees had been present.

Where loppings are dug in moreover there is the certain knowledge that part of the nitrogen in the loppings has been obtained from the atmosphere (provided nodules are found on the roots of the tree) whereas with a non-leguminous tree all the nitrogen is obtained from the soil.

Other things being equal there is therefore a strong case for the preference of a leguminous tree though the benefit to be derived is more probably a saving in loss of nitrogen than necessarily an actual gain.

(5) *Soil Erosion.*—The extent to which the planting of trees in tea will check soil erosion is limited. Nevertheless the heavy litter of leafy material produced in particular by *Grevillea robusta* or *Albizzia moluccana* is of considerable help, while the presence of trees—particularly those with a spreading habit—will to some extent prevent the direct beating of rain upon the soil.

(6) *Check to Tea Tortrix.*—In the opinion of a number of superintendents tortrix incidence is less where high shade is present. In the view of the Assistant Entomologist, Mr. F. P. Jepson, a heavy cover of old *Albizzias* may interfere considerably with the free dispersal of the moths and in this way act as a flight break. It is not thought that shade itself is unfavourable to tortrix, in fact it is stated by some planters that the pest is more prevalent in shady situations.

(7) *A Mulch of Leaves.*—The natural leaf-fall from many of the trees commonly interplanted among tea is considerable. As previously mentioned probably *Grevillea robusta* and *Albizzia moluccana* are the most useful in this respect. Apart from natural leaf fall loppings are sometimes spread and left on the surface. There is little doubt that the greatest good is obtained from loppings if they are incorporated green into the soil. The question of labour however often precludes this being done at every lopping and it is certain that the spreading of such loppings over the surface of the ground is beneficial.

In dry weather a mulch of leaves will greatly help to retain soil moisture and, as has been mentioned in discussing the question of shade tea could theoretically be best helped as regards moisture by lopping shade trees at the beginning of a drought and spreading the loppings on the surface. One drawback to this system is that the shade trees themselves are left to recover from the lopping in the most unfavourable circumstances. Anstead [2] says that this practice is frequently adopted in India. The superintendent of an up-country estate reports that he allows dadaps, *Grevilleas*, and *Acacias* to grow up unlopped as he considers the leaf-fall is equal to lopping. The meaning of this statement is rather obscure. It cannot be contended that the amount of leafy material added to the soil is as great as when the trees are regularly lopped for it is well known that lopping or pruning stimulates vegetative growth. It is quite possible however that in certain circumstances the benefit obtained by the tea might be equal.

Apart from the question of moisture, fallen leaves or loppings left on the surface will eventually decay and to some extent become incorporated in the soil. The net chemical gain may not be large, but an improvement in physical condition is certain.

(8) *The Burial of Loppings.*—To obtain the maximum increase of humus in the soil by making use of the leafy material of trees planted in tea, this material should be forked in or buried.

Hope and Tunstall [21] state that the amount of organic matter in first-class tea soils varies enormously. Healthy bushes grow on soils containing as much as 60 per cent or as little as 3 per cent, but generally bushes grow more vigorously and flush more readily on soils containing a high percentage of organic matter, until a stage is reached at which the tendency is to make rank growth and yield leaf of poor quality.

Mann and Hutchinson [28] draw attention to the fact that organic matter is essential to the cultivation of tea.

The number of cases in Ceylon, if they exist at all, in which tea soils contain an excessive amount of organic matter is so small, that this possibility may be neglected. In the great majority of cases an increase in organic matter is desirable and one of the easiest ways of supplying it is to bury or fork in the loppings and fallen leaf of trees.

The practices on tea estates of dealing with trees may be summarised as follows:

1. The trees are lopped once, twice, or thrice a year, and the loppings forked in on each occasion by envelope-forking. The total cost of the operation is variously stated to be between Rs. 4 and Rs. 10 per acre. It is not always stated if the forking is done in every row or only in alternate rows but the latter method is thought to be more common.

2. Lopping as above, but spreading the loppings on the surface without burying. Sometimes the loppings are spread in lines along the contours to assist in preventing erosion. Lopping alone is said to cost between 75 cents and Rs. 2 per acre, while the whole operation of lopping and spreading may cost from Rs. 3 to Rs. 3-50 per acre.

3. Lopping as above, and spreading the loppings on the surface, except when manure is to be applied when the loppings are forked in with the manure. The cost of lopping will be the same as quoted above while an additional cost, stated to be from Re. 1 to Rs. 3 per acre, will be incurred in forking in the manure.

4. Lopping as above, and burying the loppings in pits or shallow trenches. The cost of this burying is said to be from 75 cents to Re. 1 per acre. The procedure adopted and the cost of the operation will vary with the type of tree planted and the treatment which it will stand, the elevation and climatic conditions of the estate, and—perhaps principally—the labour and funds available for such work. Practical considerations of

labour, etc., will often necessarily outweigh scientific considerations, but as this is a matter for those responsible for the policy and working of each estate an attempt will be made here to indicate the practice which from the scientific point of view should prove most beneficial.

If it is admitted that there is little likelihood of any excess of organic matter resulting from the burial of loppings on Ceylon tea estates occurring, it follows that the greater the amount of green material that can be buried the better. Joachim [22] has shown that the young leaves and tender twigs of dadaps and *Gliricidia* are richer in nitrogen, lime phosphoric acid, and potash than older leaves and twigs. This is doubtless also so with other trees, and therefore from the point of view of enriching the soil trees should be lopped and the loppings incorporated in the soil as frequently as possible. If this principle were carried to excess the amount of green material obtained at each lopping would be reduced and though the number of loppings per year would be more numerous the total weight of green material obtained might be reduced to a greater extent than would be counterbalanced by the additional richness of the loppings.

Joachim and other workers have found that loppings lose considerable value if allowed to dry before forking in. The aim therefore should be to regulate lopping so as to obtain the greatest possible quantity of young leafy material and to fork in or bury such material as often and as quickly as possible with due consideration to the questions of the supply of labour, funds, wind protection, the desirability of leaving shade during a drought, and the capability of each tree to stand frequent lopping. The last point will be dealt with in the notes on individual trees.

It is believed that certain misconceptions are current as to the extent of the actual manurial value obtained from the burying of loppings. Elliott and Whitehead [13] in discussing *Acacia decurrens* give an instance where 6,127 lb. per acre of green material was obtained in one lopping. This weight dried down to 2,289 lb. per acre. The nitrogen content was stated to be 2·82 per cent, giving 64·54 lb. of nitrogen per acre. On this basis the authors state "With nitrogen worth Re. 1 per lb. the value of this ingredient added to the soil by means of *Acacia* loppings works out at Rs. 64.54 per annum. Three loppings per annum are usually obtained and the nitrogen added to the soil each year would, therefore, be worth at least Rs. 150 which is obtained at merely the cost of the labour employed,

some Rs. 2 to Rs. 3 per acre per lopping, just depending on the growth made by the *Acacias* before they are coppiced". The burying of loppings is undoubtedly a cheap way of supplying nitrogen, but it is thought that the above statement is open to misconstruction. In the first place only a part, though possibly a large part, of the nitrogen in the loppings has been obtained from the atmosphere, the remainder has been obtained from the soil and though returned to it again cannot be considered as pure gain. Secondly, certain losses of free nitrogen will occur in the soil and it is certain that the whole quantity of nitrogen in the loppings will not be available for the tea bushes.

As an illustration of the improbability of large increases of nitrogen resulting from the burying of loppings under tropical conditions the following figures taken from Joachim and Panditteseker's report on an experiment at Peradeniya are quoted:

Plots	Per cent Nitrogen 1928	1929	Increase or decrease
Dadaps lopped and forked in	·106	·096	−·010
Gliricidia ,, ,, ,,	·109	·105	−·004
Control (bare, clean weeded monthly)	·097	·068	−·011
Tephrosia lopped and forked in	·103	·105	+·002
Crotalaria ,, ,, ,,	·096	·096	·000
Control (bare, clean weeded monthly)	·096	·080	−·017

In this experiment the growth of the dadaps was very poor and but little green material was obtained. The growth of the other plants was good and a considerable weight of loppings was obtained at every cutting. The plants were lopped as soon as they were ready and the loppings forked in by envelope forking; yet not only was no large gain in nitrogen shown but there was a small loss in most cases. Larger losses, however, were sustained by the control plots, showing that the growing of leguminous trees and the forking in of loppings had arrested the natural decrease in soil nitrogen.

Figures are sometimes quoted of the quantity of organic matter returned to the soil, based on the analysis of the loppings. It must however be borne in mind that the carbon-nitrogen ratio in loppings is usually about 10 to 1. The carbon-nitrogen ratio in the soil will remain more or less constant, and consequently unless there is a considerable supply of nitrogen already in the soil a loss of carbonaceous matter in the loppings will occur. To avoid this the application of a nitrogenous manure at the

time of burying the loppings would appear to be advantageous. This is frequently done as a saving of labour is effected by forking in loppings and manure in one operation.

It has been advised that trees should be lopped as often as possible because young leaves and twigs are richer in mineral constituents than when they are older. The suitability of weather conditions for the burying of green material is, however, an equally important point. This matter has been dealt with in Section I where it has been pointed out that the burying of undecomposed green material immediately before or during a drought is undesirable, owing to the increased loss of moisture that will result from the increase in air spaces in the soil. In the latter case the operation would in any case be impossible owing to the hardness of the ground. Decomposition will take place most rapidly in alternating periods of rain and fine weather. Here again practical considerations such as the availability of labour will necessarily determine the time chosen for the operation rather than optimum conditions from the scientific point of view.

It is probable that the improvement to the tilth of the soil is one of the most important advantages to be gained from the burying of loppings, while in districts of short rainfall the increased power of retaining moisture resulting from the addition of organic matter will assume proportionately greater importance.

(9) *The Check to Weed Growth.*—Shade almost always has the effect of considerably reducing weed growth—the relative cost of weeding young and old rubber will illustrate this strikingly. The reduction of weed growth is therefore a useful though secondary function of shade trees in tea.

(10) *The Retention of the Plant Food.*—In a new clearing the area occupied by the roots of the young tea plants must, for some time, be small. Trees planted in such a clearing therefore may take up and retain a certain amount of plant food which is beyond the reach of the tea roots and this plant food may later be returned in part to the soil in the form of leaf-fall and loppings. In the case of trees the amount of food material so taken up will usually be less than in the case of more closely planted bush plants or creepers.

(11) *Rainfall.*—Some doubts have recently been expressed as to the value of forests or plantations in conserving the rainfall of a country. The theory that trees are effective in maintaining rainfall, however, still forms one of the basic principles of the forest policy of many countries.

It is doubtful if in Ceylon trees have ever been planted among tea with the direct object of maintaining or increasing the rainfall but Mann and Hutchinson [28] record that in at least one Indian tea district *Albizzia stipulata* has been planted with the direct object of retaining the rainfall. The authors state that the rain had a habit of following the jungle covered hills and leaving the gardens untouched and the planting of *Albizzia stipulata* definitely remedied the state of affairs.

(12) *The Encouragement of Bird Life.*—Apart from the aesthetic point of view there are several species of Ceylon birds which are on occasion helpful in combating insect pests of tea while there are no birds directly injurious to tea. The provision of additional trees for birds to nest in would therefore appear to be an advantage.

The advantages of planting trees in tea have now been discussed in some detail and it is thought that a good case has been made out in favour of such planting.

There are still a few general considerations connected with the planting and cultivation of trees in tea which will be briefly discussed.

THE CHOICE OF A TREE

The notes on individual trees which are given later will, as far as information is available, give the characteristics, special advantages, adaptability, etc., of the different trees. The choice of a tree must depend in part upon the relative importance of the functions it is expected to perform and the advantages it is hoped to gain. Thus for low-country tea where shade is considered desirable *Albizzia moluccana* might probably be chosen on account of its broad spread and the light shade afforded. If on the other hand shade was not considered essential but a plentiful supply of green material was desired the choice might fall on *Gliricidia maculata*, a tree which at suitable elevations can be lopped four times a year and will yield a heavy weight of green material. Again on a very windswept estate the question of wind protection might assume paramount importance and it might be advisable to plant, at any rate the most exposed portions of the estate, with mango or other wind-resisting trees.

The local prevalence of certain pests and diseases may also affect the question of the choice of a tree.

There is a great deal to be said in favour of mixing two or more kinds of trees and this point will be discussed later.

HIGH AND LOW SHADE

The questions of the relative benefits of high shade and low shade are often discussed. The question appears to hinge to some extent on the necessity or desirability of shade as such. The term high shade is generally taken to mean shade provided by tall trees which are allowed to grow up unlopped. If shade is considered necessary or desirable the frequent lopping of shade trees and consequent periodical removal of most of the foliage would not appear desirable. Even if only alternate trees are lopped at one time, or trees are only partially lopped, the shading effect is not quite the same as if high shade is maintained. A drawback to allowing *Albizzias* to grow unchecked is that they attain great size and when they eventually die their removal is a laborious and difficult operation and entails considerable damage to the tea. If only *Albizzias* or other trees of a similar habit are grown and are left unlopped the full advantages obtained by the burying of loppings are not obtained. There would then seem to be considerable advantages in a mixture of high and low shade. Apart from the shading effect, high shade trees may be effective in reducing the incidence of tortrix attack and may give more efficient protection against wind. If unlopped, however, the amount of organic matter returned to the soil will be greatly reduced and this benefit could be obtained by planting trees such as dadaps, or *Gliricidia*, in addition to high shade.

In practice a mixture of high and low shade is frequently found on estates. The two trees most used for high shade are probably *Albizzia moluccana* and *Grevillea robusta* and in addition to these dadaps, *Gliricidia maculata* and others are frequently interplanted as low shade and to afford a supply of green material. A few actual estate examples are quoted below:

	District	Trees planted	Spacing
1.	Ratnapura	*Albizzia moluccana*	40 feet by 25 feet.
		Gliricidia maculata	15 ,, ,, 15 ,,
2.	Pussellawa	*Albizzia moluccana*	40 ,, ,, 40 ,,
		Dadap or *Gliricidia*	12 ,, ,, 10 ,,
3.	Badulla	*Albizzia moluccana*	50 ,, ,, 40 ,,
		Dadap or *Gliricidia*	20 ,, ,, 25 ,,
4.	Maskeliya	*Albizzia moluccana*	30 ,, ,, 30 ,,
		Dadaps	12 ,, ,, 12 ,,
5.	Dimbula	*Grevillea robusta*	25 ,, ,, 25 ,,
		Dadaps	15 ,, ,, 15 ,,

In some cases only one kind of tree is grown but trees at definite intervals are allowed to grow up while the remainder are lopped.

Apart from the reasons given above for planting more than one variety of tree the following advantages may be mentioned:

(i) One variety of tree may be attacked by a pest or disease to which the others are immune.

(ii) One variety may be deeper rooted than another and the two varieties therefore will not compete to the same extent for their food requirements.

REPLACEMENT AND REMOVAL

Elliott and Whitehead [13] state that it is desirable to cut out leguminous trees when they have developed thick trunks and wide-spreading root systems.

It is impossible to lay down a hard-and-fast rule in this matter. Trees grown for high shade will not of course be replaced unless they die, but there is a fairly general opinion that dadaps should be replaced and removed when they attain a certain age or size, though opinions as to the correct age or size differ widely. If the trees are grown principally to produce green material it would appear reasonable to replace them when the amount of leafy material produced in proportion to the size of the stem and roots showed considerable diminution. In the case of some trees such as *Albizzia moluccana* the inconvenient size to which they attain affords another reason for periodical replacement and removal. It is to be noted that replacement is mentioned before removal since it is always advisable to plant the new trees some time before the removal of the old ones so that the ground is not denuded of all tree growth.

NOTES ON INDIVIDUAL TREES

The following list of trees on which notes are given include trees actually grown in tea in Ceylon or elsewhere as well as trees which might prove useful for planting in tea in Ceylon. The list is by no means exhaustive and in some cases the available information is very meagre. Cases frequently occur in which a plant which has become well known under one botanical name is held by botanical authorities to be incorrectly named and the name is changed. These occurrences cause confusion and in this section the botanical names by which plants are generally known are used while a note is inserted at the end of the section indicating recent changes in the botanical names of the plant dealt with. Common names are given where they exist and are in common use. Only Ceylon vernacular names are inserted.

Acacia decurrens, Black Wattle.—This tree is largely grown in tea at elevations from about 4,500 feet upwards. Several reports of lack of success at lower elevations have been received. An estate at 3,800 feet at Ambegamuwa reports that the trees usually die out in four years, and on an estate at Dickoya at 4,000 feet it is reported that the trees do not live long and are subject to root disease.

Propagation is from seed. The seed is hard and to obtain quick germination soaking in hot water is desirable. Elliott and Whitehead [13] state that seed is sown in nurseries and the seedlings transplanted to the field when 4 to 6 inches high. Holing is said to be not necessary. Some estates use self-sown seedlings for preference as these are found to be hardier. An estate at Maturata finds the tree hard to establish and therefore allows self-sown seedlings to grow up and these are thinned out later. An estate at Nuwara Eliya reports that the roots of seedlings are always soaked in liquid manure before planting out.

The spacing adopted by estates varies between 15 feet by 15 feet and 30 feet by 20 feet. 15 feet by 20 feet might be taken as a fair average. In windy districts the trees are sometimes planted in thick belts.

The trees are usually lopped. Three loppings a year is the maximum but two loppings is more usual, while some estates lop only once annually. The practice on a certain estate at Nuwara Eliya is to lop lightly once between October and February and again more closely in May or June. Some estates stress the importance of close lopping before the south-west monsoon in order to minimise the incidence of the leaf disease *Cercosporella theae* which spreads from *Acacias* to tea. Deaths after lopping appear to be of fairly common occurrence and the tree cannot be said to stand lopping really well. The cost of lopping is given as between Rs. 3 and Rs. 3-50 per acre. It is the general opinion that *Acacia decurrens* grows too big in time and requires uprooting though opinions differ as to the age at which this should be done. For example two estates (one in Dickoya and one in the Agra Patanas) give the limit of useful life at 4 to 5 years, but in these cases it may be taken that the elevations are possibly too low to be really suitable for the tree. A Haputale estate places the age at 12 to 15 years, while on an estate at Pundaluoya the trees are uprooted when the circumference at 3 feet is about 18 inches. One superintendent advocates the judicious cutting away of *Acacia* roots at every round of forking.

The chief objection to this tree is probably its susceptibility to the disease *Cercosporella theae*, which is worst in districts subject to much mist. The incidence of the disease may be lessened by close lopping before the south-west monsoon but it is regarded so seriously in some quarters that a number of estates have gone to the length of cutting out all *Acacias*. On the other hand some estates (Maturata, Hewaheta, and Maskeliya) report that the disease is never serious. Fluted scale has been reported on *Acacias* in dry weather but the pest disappears with the rains. Deaths of *Acacias* for no apparent reason are reported to be fairly frequent. In clearings the roots of *Acacias* are said to be apt to strangle young tea plants. The tree certainly has disadvantages but as a means of supplying green material and for protection against wind it is of great value. It also affords a valuable source of fuel and the wood is useful for fence posts. No really suitable substitute for *Acacia decurrens* at high elevations has been found. The bark of the tree forms a well-known tanning material, but attempts to foster a local industry in this product have not succeeded.

Acacia melanoxylon, Australian black wood.—This is a large tree which was tried in tea on several estates in Ceylon in 1907 but reports differ considerably. One estate reported that the tea was benefited but another stated that on account of its spreading root system the tree was injurious to tea. No more recent information is available.

Acrocarpus fraxinifolius.—This tree has been grown in tea in Dimbula, Maskeliya, and elsewhere but very little information is available. It seems liable to attack by pests notably *Terias silhetana*, the *Albizzia* caterpillar, which in some cases strips the tree bare of foliage . Apart from this it affords useful shade and gives a fair leaf-fall.

Albizzia Gamblei.—One of the *Albizzias* grown in tea in the Darjeeling districts in India.

Albizzia Lebbek, Mara (Sinh), Kona Vakai (Tam.).—This tree is indigenous to Ceylon but although grown in tea in the Darjeeling districts it has not to the writer's knowledge been cultivated in Ceylon. It is a large tree with spreading but somewhat straggly habit. It is said to be subject to attack by a number of insect pests.

Albizzia lopantha, Brush wattle.—This small tree has been tried on a number of estates at high elevations as a substitute for *Acacia decurrens* but reports do not indicate great success. Gadd [14] reports that it is just as liable to *Cercosporella theae*

as *Acacia decurrens*. Light [26] also reports it to be severely attacked by tea tortrix and other leaf-eating caterpillars as well as by a species of mealy bug.

Two superintendents report good growth at 5,000 feet but others state that it will not stand wind. It appears also very liable to root disease. All things considered the tree appears of little use as a substitute for *Acacia decurrens*.

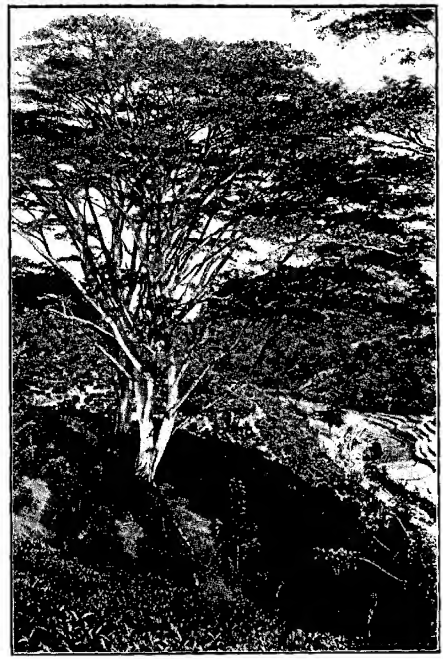
Albizzia fastigiata.—No information is available as to the trial of this tree in tea but specimens growing in the Royal Botanic Gardens, Peradeniya, show a remarkably fine growth and a spread even larger than that shown by *Albizzia moluccana* to which the tree shows close resemblance.

Albizzia moluccana.—This is one of the best known high shade trees in Ceylon. It is a large tree with a spreading habit and light feathery foliage. It is also grown in India but to a less extent than *Albizzia stipulata*. It can be grown at almost any elevation in Ceylon but is less successful at higher elevations and its inability to stand strong wind is a further disadvantage. Elliott and Whitehead [13] state that it does well up to 4,000 feet.

Propagation is always from seed as cuttings are seldom successful. Soaking the seed in hot water will hasten germination. Basket plants are said to be most successful but seed at stake is often used, 3 to 6 seeds being sown together. If planted 25 feet by 25 feet, 6 seeds together, one pound of seed is said to be enough for 20 acres. Other estates plant out larger nursery plants stumped to 2 feet or 2 feet 6 inches high. Holing in any case is advised.

Spacing will depend on whether the *Albizzia* is grown alone, or in conjunction with other trees, and also on the treatment it is intended to give the trees. If they are to be lopped closer planting can be adopted than if they are planted solely for high shade. A great variety of planting distances is reported by estates, ranging from 10 feet by 10 feet to an eventual stand of 70 feet by 70 feet. Probably 30 feet by 30 feet can be taken as an average where *Albizzia* is planted alone. When mixed with dadaps the following examples of estate spacing may be quoted:

Albizzia	Dadaps
20 feet by 20 feet	10 feet by 10 feet
20 ,, ,, 20 ,,	16 ,, ,, 16 ,,
40 ,, ,, 40 ,,	12 ,, ,, 10 ,,
35 ,, ,, 35 ,,	10 ,, ,, 10 ,,
16 ,, ,, 16 ,,	16 ,, ,, 16 ,,



Albizzia moluccana in tea

One of the chief drawbacks of *Albizzia moluccana* is the large size to which it attains. This growth can be kept in check by regular lopping from a comparatively early age. The tree, however, does not generally stand loppings well and the dying off of the bark of large branches or even the death of the tree is not uncommon. Moreover, the weight of green material obtained per acre is substantially less than that which can be obtained from dadaps or *Gliricidia maculata*. If grown in conjunction with other trees *Albizzias* are usually used for high shade and to afford some measure of protection against tortrix. In this case the trees are not lopped. In other cases a proportion of the trees are lopped and the remainder allowed to grow up for high shade. Some estates report that they have given up lopping *Albizzias* on account of the casualties that result. Lopping too early nearly always results in damage. A Dolosbage estate does not lop till trees are 18 inches in girth at 3 or 4 feet from the ground. Up-country estates usually start pollarding *Albizzias* at 10 to 15 feet. Lopping is done at intervals varying between twice a year and once in 18 months. When lopping it is always advisable to leave a number of unlopped branches on the trees, otherwise death is liable to result, especially if dry weather follows lopping. Sometimes lopping is only done at the time of manuring. The weight of green material per acre obtained from lopping *Albizzias* will always be considerably less than that which can be obtained from lopping dadaps, *Gliricidia*, or *Acacia decurrens*, and in view of this and the inability of the tree to stand hard or frequent lopping it would appear preferable to make use of one of the above trees as a source of green material and to plant *Albizzia moluccana* only for high shade. An experienced superintendent of an estate in the Southern Province is of the opinion that *Albizzias* are excellent shade trees for tea but should never be lopped.

The question of the removal of old *Albizzias* in tea is an important one and is beset with considerable difficulties. As usual, opinions differ. Some are of the opinion that old *Albizzias* do no harm to tea but the general consensus of opinion is that the trees get too big and must periodically be removed. One superintendent states that the trees get out of hand at 5 years of age but the more general opinion is that they should be cut out after 8 to 12 years in the low-country and after about 15 years up-country. One mid-country estate reports that the trees are cut out when the girth exceeds $2\frac{1}{2}$ feet at 18 inches from the ground. Some estates advocate ringing old trees and one superintendent states that the roots rot very fast and root disease in tea seldom results. On the other hand a superintendent in

Morawak Korale says that *Albizzias* are responsible for a great deal of *Ustulina*. Others are averse to ringing as dead branches fall on the tea and are also a source of danger to coolies. One superintendent points out that if the branches are not lopped before felling much less damage will result to tea. The operation of eradicating large *Albizzias* is in any case very laborious and expensive and is bound to result in considerable damage. With these disadvantages it would appear questionable whether *Albizzia moluccana* is worth planting in tea, and yet it is certain that tea under *Albizzias* almost always appears healthy, even bushes close up against the stems of large trees. Figures as to the comparative yield of bushes from far and near to *Albizzias* are not available in Ceylon but striking figures in this connection have been quoted with regard to *Albizzia stipulata* in India. Probably the best solution is to use *Albizzias* unlopped as high shade mixed with other smaller shade trees and thus reduce the number of large trees per acre which will eventually have to be eradicated. The rapid growth and light filtered shade of *Albizzias* are two further points in their favour while it is probable that their root action is of especial benefit. An instance is given from Maskeliya of an abandoned field under *Albizzia*; when the tea was again taken into cultivation it was found to be in excellent health and subsequently gave 700 lb. per acre.

Among disadvantages must be reckoned susceptibility to various pests and diseases especially *Terias silhetana*, the *Albizzia* caterpillar, which especially defoliates the trees both in the low-country and up-country. Light [25] speaking of a serious outbreak of this pest where 400 acres were completely defoliated states that some trees which had been allowed to grow up to 30 or 40 feet unlopped were practically undamaged though standing among smaller trees which had been severely attacked. *Calotermes militaris* has in some districts also proved a serious pest of *Albizzia*. The wood of *Albizzia moluccana* is of value for making chests. It is also stated that the tree will often grow on poor soil where it has been found impossible to establish other trees.

The drawbacks to *Albizzia moluccana* are many but its marked merits make one hesitate to recommend its rejection as a high shade tree for tea.

Albizzia odoratissima, Suriya mara (Sinh.), Ponnaimurankai (Tam.).—This tree is grown as a shade tree for tea in certain districts in Assam, particularly on very light grey soils. It is also grown in the Darjeeling districts. It is said to be very

Albizzia procera

Albizzia stipulata

beneficial to tea. A specimen in the Royal Botanic Gardens, Peradeniya, shows a straggly habit and poor thin foliage, but the tree is probably old.

Albizzia procera, White siris, Kondha Vagha (Tam.).—A large spreading tree conspicuous for its yellowish white bark. It is said to be commonly grown in tea gardens in the east of the Duars where the growth is said to be slower than that of *Albizzia stipulata*.

Plants grown at Peradeniya from seed imported from Assam have made good growth. Some of the trees have been lopped and have recovered well. Reports from higher elevations, however, speak of unsatisfactory growth.

Albizzia stipulata, Sau, Kabal mara, Hulan mara (Sinh.).—This tree is but little known in Ceylon but is of immense importance in northern India. Anstead [2] says that it is largely grown in tea in India and is lopped at the beginning of the dry weather. It is believed however that more often the tree is not lopped. Bald [6] describes it as the most favoured tree for planting among tea in northern India. He says that the loppings form a valuable mulch and that the light foliage does not overshade the tea. Mann and Hutchinson [28] state that it becomes almost leafless in the hot dry weather. It is very deep rooted and considerable store is set on its root action. It is propagated from seed which is freely produced. The tree is stated to be very indifferent to soil differences. The timber is more valuable than that of *Albizzia moluccana* and it does not grow so big or so fast. Reports of the use of this tree in Ceylon have been received from Haputale, Welimada, Wattegama, Morawak Korale, and Kalutara. The superintendent of an estate in the Morawak Korale describes the tree as superior to *Albizzia moluccana* as it does not grow so big or so fast. These are not very convincing advantages and the other reports are in the main unfavourable. A few trees grown at the Experiment Station, Peradeniya, have not given great promise. The growth is comparatively poor and the trees do not stand lopping well.

Cassia didymobotrya, Candelabra tree.—This small tree has a handsome yellow flower and is often grown in gardens as an ornamental tree. It has been extensively cultivated in tea on an estate in Dickoya and on another near Nanuoya.

It is easily propagated from seed but cuttings are said not to be successful. This tree flourishes in the mid-country and at all higher elevations. It appears hardy, free from pests and diseases, has a very convenient habit and stands lopping well. The tree flowers profusely twice a year. This is its

only obvious disadvantage as normally a tree should be lopped before it flowers. Loppings from a tree in flower, however, were sent for analysis and reported to be rich in mineral constituents. The weight of loppings which can be obtained per acre is obviously considerable. On the Dickoya estate mentioned the tree was being planted in places where dadaps were not doing well and formed a valuable substitute. Many estates have areas where dadaps do not flourish and a useful substitute will have considerable value.

When young the stems are said to be somewhat weak and staking may be required. The trees may be lopped twice a year or oftener.

Cassia multijuga.—The possibility of using this tree in tea has been discussed by the staff of the Tea Research Scheme. It is thought, however, that the tree is not sufficiently hardy to be of any great use.

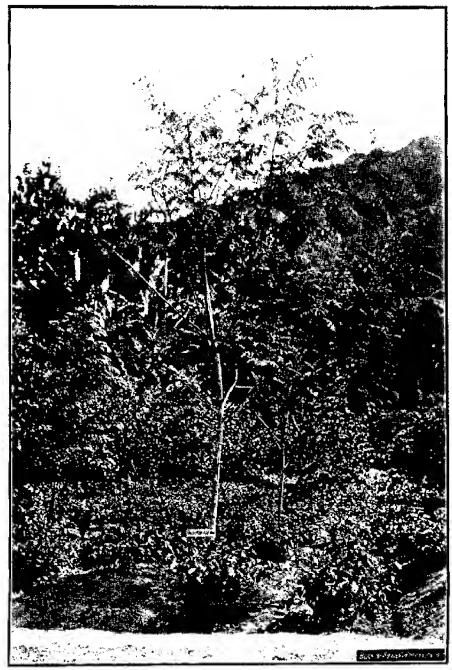
Dalbergia assamica.—This native of Assam has been introduced to Ceylon tea estates in recent years. The circulars received back from estates contained only two reports on this tree though it is believed that it is being grown on a larger number of estates.

An estate near Gampola says that the tree is thriving well, while an estate at Haputale records that the tree is growing, but gives no further information. Trees planted from seed on the Experiment Station, Peradeniya, in 1928, are making remarkably rapid and healthy growth.

Derris dalbergioides.—This is a medium sized tree native to Burma and Malaya which is being grown on a tea estate at Haputale. No information is given.

Derris microphylla.—Information as to this tree is mainly from Java where it is stated to be coming into considerable favour as a shade tree for tea. The following advantages are given:

1. It thrives from sea level to 1,100 feet and probably higher.
2. It is leguminous and forms many nodules.
3. It gives a serviceable shade throughout the year and does not require much pruning.
4. Growth is rapid.
5. It stands wind well.
6. It is largely immune to pests and diseases.
7. It furnishes good firewood and the wood can be used for making boxes and for building.



Dalbergia assamica—18 months old

Derris robusta

Erythrina lithosperma in tea
Pithocolobium saman in background

If the range of elevation is similar in Ceylon the usefulness of the tree would be principally confined to low-country tea. The description is attractive, however, and it is interesting to note that an estate in Kalutara is growing it and describes it as an excellent shade tree for tea. The superintendent states that it stands wind well, is free from disease, and gives a fair leaf-fall.

The tree appears to be a most promising acquisition and well worthy of more extended trial.

Derris robusta.—Seed of this tree was imported into Ceylon from Assam, in May 1926, and distributed to several estates. Seedlings at Peradeniya were attacked by the Kalutara snail but those which survived have grown into handsome healthy trees.

Only six estates have furnished reports on this tree in their replies to the circulars. An Uva estate at an elevation of 4,000 feet reports that the tree was not a success. The tree apparently requires a lower elevation but appears well worthy of trial in the mid and low-country. It is attacked by shot-hole borer.

Erythrina lithosperma, Dadap, Eramudu (Sinh.), Murunka (Tam.).—This is quite the most common tree used in tea in Ceylon. It is also considerably used in south India. The highest elevation at which it can be really most successfully grown appears to be about 5,000 feet. At the higher elevations it is often reported that it can be grown in sheltered situations but not on wind-blown slopes. The tree can be grown at low elevations but generally speaking does not seem to be very successful below about 1,000 feet.

The tree is occasionally propagated from seed in which case the seed is usually sown in nurseries or baskets and the seedlings planted out later. The use of cuttings is, however, far more general and is to be preferred. Elliott and Whitehead [19] recommend the planting of 4-foot cuttings in prepared holes at an angle of 60 degrees with the ground, inserting 18 inches of the cutting in the ground.

The object of planting cuttings sloping is to enable the earth to be rammed more firmly round the cutting. This is certainly a point of great importance. On the other hand this method entails more trouble in training one upward shoot to form the future tree and removing others. If upright cuttings of sufficient length are used, and these shoot satisfactorily from the tops the original cutting forms the main stem and a tree of the desired shape is more easily produced. Probably 6-foot

cuttings are more generally used and are likely to be the most successful. One estate reports greater success with a forked 6-foot cutting than with a plain one. Cuttings taken from the central branches of the tree are said to be more successful than outside branches. Holing is generally done but is by no means universal. A hole 18 inches deep and wide is usually considered to be sufficient. Often planting is done in alavangoe holes. Cuttings frequently die back to a considerable distance from the top and some estates adopt the practice of tarring the tops of cuttings or dipping them into Skene's wax and claim considerable advantage from the practice in the prevention of die-back.

An almost infinite variety of planting distances are found on estates. When planted alone spacing varies between 9 feet by 9 feet and 20 feet by 20 feet, but intermediate distances of 12 feet by 12 feet to 16 feet by 16 feet are most common. The actual spacing must depend on the spacing of the tea. Any closer spacing than 14 feet by 14 feet is likely to cause too dense a shade and to increase unduly the cost of lopping. Dadaps are frequently planted with *Albizzia moluccana*, the latter tree forming the high shade. A few actual estate examples of spacing employed in such mixed planting are given.

Dadaps	Albizzia
10 feet by 10 feet	20 feet by 20 feet
16 ,, ,, 16 ,,	20 ,, ,, 20 ,,
12 ,, ,, 12 ,,	30 ,, ,, 30 ,,
10 ,, ,, 12 ,,	40 ,, ,, 40 ,,
10 ,, ,, 10 ,,	35 ,, ,, 35 ,,

Dadaps as low shade are often interplanted with *Grevillea robusta* as high shade. In such cases planting distances will be very similar to those quoted above except that the *Grevilleas* may be planted somewhat closer than *Albizzias*. Sometimes dadaps, *Grevilleas*, and *Albizzias* are interplanted. In other cases dadaps and *Gliricidia maculata* are mixed, with or without high shade.

In the large majority of cases dadaps on tea estates are periodically lopped. The frequency of loppings depends on the rate of growth (which is influenced by the elevation and climate), the labour supply, the manuring programme, and other practical considerations. The maximum possible number of loppings in very favourable conditions may be four per annum; usually not more than three will be possible, and in dry districts or at high elevations less than this. It is common to lop only

one line at a time so as to remove all shade simultaneously. Sometimes, though somewhat rarely, the dadap is used as high shade, in which case trees at fixed intervals, or possibly whole rows, will be left unlopped. One estate in lower Dickoya reports that lopping results in the death of the trees. A few estates only trim up the side branches.

The cost of lopping and spreading the green material from dadaps, apart from any burial or forking in, is stated to be between 60 cents and Rs. 2 to Rs. 2·50 per acre. The more usual figure is in the neighbourhood of Re. 1·50.

The general estate practices with regard to the disposal of green material have been described and commented on. With dadaps the cost of forking in loppings by envelope-forking in alternate lines is given as between Rs. 4 and Rs. 7 per acre, or say, including lopping and spreading Rs. 6 to Rs. 10 per acre. Burying loppings in pits is not so general. The cost will probably be rather less than that of forking in. One estate gives the cost as Rs. 4·50 per acre per round.

The actual lopping should be done with some care; the dadap is a fairly hardy tree but repeated hard lopping is likely to result in dieback or even death.

Bamber [6] gives the annual average weight per acre of loppings of dadap at the Experiment Station, Peradeniya, as 9,622 lb. For a later period dadaps planted 16 feet by 16 feet, giving 170 trees to the acre yielded 12,212 lb. per acre per annum over a period of five years.

There is a very general opinion that at a certain age dadaps should be replaced and dug out but the age at which this should be done is more or less a matter of conjecture. Wright [36], writing a good many years ago, recommends that dadaps in tea should be uprooted every year and replanted. Few would be found now to agree with such a view. The estimate of the useful life of a dadap tree is generally estimated by estates to be about 10 years in the low-country, and 15 up-country. A good deal depends on the treatment the trees have received. One up-country superintendent says that by regular lopping the size of the trees will be kept down and states that he has seen 15-year-old dadaps no bigger than a man's leg and still vigorous. Some 18-year-old dadaps were dug out at Peradeniya; the roots were well provided with nodules, the trees were still providing a fair weight of loppings and appeared to be doing useful service. Other estates remove trees when they attain a maximum girth, e.g., 16 to 18 inches. The question

is difficult and no rule can be given. The green manure experiment now in progress at Peradeniya may shed some light on the matter in the course of years. Clean extraction, preferably by monkey jack or wrinch, is advisable.

The dadap is subject to a number of pests and diseases but they are scarcely of sufficient seriousness to become a limiting factor in the planting of the tree and therefore do not call for detailed comment in this section. Probably eelworm is the most serious pest of dadaps at the present time, both on up-country and mid-country estates.

The wood of the dadaps is of little use except for smoking rubber or brick making. There is no disputing the fact that tea does well under dadaps. Plots at Peradeniya which have received no nitrogen for years other than that obtained from dadap loppings have throughout maintained their yield and healthy appearance.

The tree is certainly a valuable asset to tea estates over a considerable range of elevation.

Gliricidia maculata.—For a number of years the Department of Agriculture has drawn attention to the valuable properties of this medium-sized tree as a shade and green manure tree for tea.

The tree flourishes from sea level up to about 3,000 feet. Several reports have been received of lack of success at higher elevations.

The tree can be propagated from seed or cuttings. The latter is the easiest method and moreover good seed is not easy to obtain on account of insect attack. Many estates use short cuttings of about 3 feet planted sloping. If cuttings are scarce this may be economical but long vertical cuttings shoot so readily from the top that their use is always to be preferred and produce a tree of desirable shape much more quickly. Most estates use 6-foot cuttings. Some estates dip the ends of the cuttings in Skene's wax or some such waterproof material, but this is scarcely necessary as the tree is very easily established in suitable districts.

The tree is very much the same size as the dadap and planting distances are consequently similar. *Gliricidia* is very often interplanted with *Albizzia* or *Grevillea* and in this case also spacing will be similar to that used for dadaps.

Gliricidia maculata in tea

Grevillea robusta in tea

The trees are usually lopped periodically. Rather more frequent lopping is possible than with the dadap. At Peradeniya dadaps usually afford three loppings a year but *Gliricidia* always four. Moreover the severest lopping can be employed without fear of damage. In districts suitable to both trees the weight of loppings from *Grevillea* will always be in excess of that from dadaps. Over a period of 5 years, *Gliricidia* at Peradeniya planted 16 feet by 16 feet yielded 24,514 lb. of green material per acre per year compared with 14,546 lb. from dadaps of the same age and with the same spacing.

It may be mentioned that it is necessary to lop the first growth fairly early or the tree will become top heavy and liable to be blown down. The tree is sometimes grown for the sake of its light shade and left unlopped. This is not the best way to make use of *Gliricidia*, since the large quantity of green material afforded by lopping is one of its great advantages.

The opinion that *Gliricidia* should be replaced at a certain age is not so frequently expressed as is the case with dadaps, 8 to 12 years is given by some as the economic life of a *Gliricidia*. As the tree has been compared with the dadap it may be convenient to tabulate its advantages:

1. Easier to propagate in suitable districts.
2. Superior resistance to drought and wind.
3. A heavier yield of green material.
4. Stands harder lopping.

Freedom from pests and diseases is one of the advantages usually ascribed to this tree. In certain drier districts, however, the tree is somewhat seriously attacked by scale insects, e.g., *Pseudococcus virgatus*, *Pseudococcus citri*, and *Coccus viridis*, the green bug. The latter pest has in certain instances spread from *Gliricidia* to tea and has caused some apprehension. It is believed, however, that if the *Gliricidia* was kept regularly lopped the danger from these pests would be greatly diminished.

It is said that neither cattle, goats, nor sambhur eat the leaves and this in itself is a considerable advantage.

Gliricidia is undoubtedly one of the most valuable of low shade trees and has certainly come to stay.

Grevillea robusta, silver oak, silky oak, Savuka maram (Tam.).—Though not leguminous this is considered by many superintendents to be the most valuable tree for tea. Though more common at higher elevations the range of this tree appears

to be practically unlimited in Ceylon. Some estates report that the tree is hard to establish and the growth is slow, but this cannot be a matter of elevation since the complaint comes from estates of widely different elevations.

Propagation is by seed sown in nurseries or baskets. Sometimes large stumped nursing plants are planted out in the field, sometimes small plants 5 to 6 inches high. When small plants are used pegs are necessary to mark the spot. Basket plants are most successful.

The arrangement and spacing of the trees differ widely. Some estates plant windbelts only, some plant the trees along roads and boundaries, and some plant among the tea, with or without the addition of windbelts, roadside, or boundary lines. *Grevillea* is often used for high shade in addition to dadaps or *Gliricidia*. The following are examples of spacing employed by estates when *Grevillea* is planted alone: 30 feet by 30 feet, 20 feet by 40 feet, 30 feet by 15 feet, 20 feet by 20 feet. When planted in addition to dadaps and *Gliricidia* one estate plants 30 feet by 30 feet and another 100 feet by 40 feet. For windbelts one estate plants 15 feet by 15 feet. Another estate plants windbelts 25 to 30 feet wide and 300 to 400 feet apart.

Regular lopping of *Grevillea* is not generally practised. Low side branches are usually trimmed up. A Haldummulla estate cuts the trees across at 15 to 20 feet to induce a spread and claims that this practice saves damage by wind and makes it easier and cheaper to eventually cut out the trees. The superintendent of a Matale estate reports that *Grevilleas* were formerly lopped every 8 years but as poor foliage resulted and the trees were found to be more liable to root disease and gummosis the practice was given up. Some estates recommend that the trees should be periodically coppiced and a new shoot allowed to grow up.

There is again considerable difference of opinion as to the age at which *Grevilleas* should be eventually replaced and eradicated, and this would appear to depend largely on the district and suitability of soil. A Haputale estate reports that *Grevilleas* die out in patana soil in from 8 to 10 years, a Badulla estate reports that trees over 25 years old are gradually killed out by gummosis, while a Dimbula estate states that "40-year-old plants are now approaching the limit of useful life". Some estates cut out *Grevilleas* when they reach certain dimensions of girth but in the case of this tree it would appear to be a question of deterioration rather than size.

Leucaena glauca

Root disease has frequently originated from coppiced *Grevilleas* which have failed to shoot again and clean eradication in such cases is highly desirable.

The re-establishment of *Grevilleas* in old tea is sometimes reported to be impossible. Complaints of this nature have been received from Dimbula which district is apparently not particularly suitable for *Grevilleas*. At least one estate in that district, however, has shown that with care *Grevilleas* can be established in old tea.

Loranthus is the most general pest of *Grevillea*.

The particular value of the *Grevillea* is ascribed to the copious litter furnished by the constant dropping of leaves. The litter will be incorporated in the soil when manuring or forking is done, but as this is practically never incorporated in the green state it has therefore lost a considerable amount of value before it enters the soil. The root action of *Grevilleas* is extensive and to it great value is attached.

Leucaena glauca.—This small tree is one of the oldest green manuring plants cultivated in the Dutch East Indies (under the name of Lamtoro) where it is said to flourish up to 3,500 feet. The indications are that its range in Ceylon is similar—the growth of the tree in Dimbula and Dickoya at about 4,000 feet is unsatisfactory. Some mid-country estates have tried the tree in tea but their reports are not favourable.

Propagation is from seed. The seed has a very hard coat and should be immersed in hot water and allowed to soak for 24 hours before sowing.

The tree has a feathery foliage and gives a light shade but as a source of green material it cannot be compared with the dadap or *Gliricidia*. It is too small as a high shade tree and therefore does not appear to perform any particularly useful function in tea.

The tree seeds profusely from an early age and the seedlings if once allowed to get a hold are hard to eradicate. The seeds when boiled and crushed makes a useful cattle food. The wood is stated to provide excellent fuel.

Pongamia pinnata, Karanda (Sinh.), Punkum (Tam.).—This is a large tree that has been planted among tea in Urugala. It has been planted mainly as a protection against wind for which purpose it is said to be very suitable.

BUSH PLANTS

The use of bush plants, nearly always leguminous, in tea cultivation in Ceylon is less general than the use of trees. Nevertheless a number of such plants are grown and with undoubted benefit. If shade for the tree is considered to be desirable the tree forms must be considered superior. To provide shelter from wind bush plants will not generally be considered very effective neither will they be of use in maintaining rainfall or encouraging beneficial birds.

One of the principal drawbacks to bush plants is their tendency to interfere with the growth of tea bushes and hinder the movement of labour in the rows. Apart from these disadvantages bush plants will confer most of the benefits to be derived from the growing of trees and in one or two respects will be found superior.

The use of bush plants varies between the planting at comparatively wide intervals of the more long-lived varieties such as *Tephrosia candida* and their retention, with periodical lopping, for a number of years, and the thick sowing of quick-growing short-lived varieties, such as the various species of *Crotalaria*, to be hoed or forked in at an early age. Intermediate between these two practices is the method of taking one or two loppings from the plants and then after one, two, or three years to uproot them and dig them in.

The first practice—that of using a bush plant in practically the same manner as a tree—is seldom found in Ceylon but is apparently sometimes adopted in India. An illustration in an Indian publication shows *Tephrosia candida* bushes widely spaced allowed to grow to their full height, and trimmed up at the sides. There would appear to be but little advantage in such a practice when there are trees that will serve the purpose more effectively.

The system of retaining bush plants for one, two, or three years only (depending on the kind of plant used and the rate of growth) would appear generally preferable, while the thick sowing and early incorporation of the quick-growing kinds may, in certain circumstances, result in considerable benefit, particularly in clearings.

The advantages to be derived from the cultivation of bush plants in tea will now be briefly discussed in the same order as was adopted in the case of trees.

SHADE

To shade tea, bush plants are of little use and they are not planted for the purpose. To shade the ground they can be put to effective use, more particularly in young clearings.

SHELTER FROM WIND

Rows of bush plants, particularly if planted across the direction of the prevailing wind, may help to protect the tea, but partly on account of their comparative impermanence, such plants cannot be considered as effective as trees for this purpose.

ROOT ACTION

The more deeply rooting bush plants, such as *Tephrosia candida*, will exercise considerable benefits in opening up the soil. The effect will not be so deep as that exercised by trees but the larger number of plants per acre will increase the area over which the action is felt. Hope and Tunstall [21] in comparing the use of bush plants with ground covers point out that the comparatively deeper root action of bush plants may prove actually disadvantageous since they will draw their moisture from those parts of the soil from which the tea bush draws its own supply. This drawback would not however be greatly felt in the wetter districts.

NITROGEN ASSIMILATION

All the remarks made with reference to trees apply equally or with greater force to bush plants. With greater force possibly because the complete return to the soil of the bush plant, and therefore the nitrogen it has assimilated from the atmosphere, is in some cases possible, whereas with trees it is not.

SOIL EROSION

Though not so effective as a ground cover plant more use can be made of bush plants than trees in the checking of soil erosion, a complete cover of low bush plants would sensibly decrease erosion but this is not generally feasible if only because there is no room for such a stand and it is probable that tea would suffer from the competition of a thick continuous stand of bush plants. It remains then to arrive at an arrangement of planting which will be most effective in checking erosion, and to choose the most suitable plant for the purpose. Obviously the best way to make use of bush plants for this purpose is to plant them in thick contour hedges. If the tea were also planted in contour lines a very effective barrier to erosion would thus be formed, but if, as is usual, the tea is planted in straight

lines without reference to the slope of the land the contour hedges and lines of tea will run in different directions. Coolies must pass up and down the tea lines and in doing so are bound to make gaps in the contour hedges and thus decrease their value. In young clearings where there is less movement of labour this objection does not apply with equal force. Such hedges are frequently planted above drains and roads and undoubtedly help in checking erosion.

The choice of a plant for this purpose is a vital matter. Hedges of *Crotalaria* and other such impermanent plants are sometimes seen. Such plants die out in a year or two and the soil that is banked up against them is then mostly lost. Unless then a practically permanent plant can be found contour hedges can be of little lasting value. *Clitoria cajanifolia* has been found to be a most suitable plant for this purpose. It is very deep rooted, hardy and will stand repeated lopping with impunity, there is no difficulty about keeping it under control. In the soil erosion experiments at Peradeniya hedges of *Clitoria cajanifolia* have effectively decreased soil erosion and after a life of five years have given no trouble and shown no loss of efficiency. Such hedges are to be found on several estates and the planters who have had experience of this plant have formed a high opinion of its value.

The considerable litter of leaves shed by some bush plants, particularly *Tephrosia candida* is of assistance in checking erosion.

A MULCH OF LEAVES

A mulch of leaves or loppings from bush plants will exercise the same beneficial effects as that afforded by a mulch from trees.

No opinions have been recorded by planters as to the advisability or otherwise of leaving bush plants unlopped during a drought, but theoretically again such plants should be lopped before a drought so as to achieve the double object of reducing transpiration from the leaves and checking surface evaporation from the soil by means of a mulch.

As in the case of trees, green material left on the surface of the soil will eventually decompose (though with certain loss of valuable constituents) and increase the humus content of the soil.

THE BURYING OF GREEN MATERIAL

As mentioned, one method of using these plants is to sow thickly and dig in the entire plant at an early age. This practice is rarely adopted in Ceylon but is fairly common in India,

though a creeper is more frequently used for the purpose. Hope and Tunstall [21] state that daincha (*Sesbania cannabina*) is usually sown out at the rate of 15 to 30 pounds per acre after a light hoeing and is then hoed in about 2 months later. The weight of complete daincha plants pulled up from an area of tea on an Assam estate was found to be equivalent to 7,500 pounds per acre. The effect of such a thick cover would certainly be to reduce the soil moisture by transpiration, but if the crops were dug in sometimes before the dry weather there would probably be an eventual gain in moisture which would more than counterbalance the temporary loss.

The usual Ceylon practice, where bush plants are used, is to sow the plants in alternate rows, take one or more loppings and then pull up the plants, possibly burying the roots. The treatment of the different plants used will be dealt with in more detail in the notes that follow. As in the case of trees, loppings are either forked in by envelope-forking on each occasion or they are left on the surface and forked in only when manuring is to be done. As the plants will take up most of the space in the rows in which they are planted it will be more convenient to throw the loppings into the adjoining rows. It is customary to pile tea prunings into alternate rows and it is a common practice to fork in a pruning mixture together with the leaves from the prunings. If bush leguminous plants are sown in these rows the seedlings will have the benefit of the loosened soil and of the manure and should make a good start. The plants can then be lopped as often as their growth and nature allow and the loppings thrown into the adjoining rows to be forked in or buried in pits as often as circumstances permit. At the next pruning the plants can be pulled up and the roots thrown into the rows in which the loppings have been placed. These are the rows which will receive the pruning mixture and the roots can be buried when this is forked in. A fresh crop can then be sown and the previous cycle of operations repeated. Some of the nodules will be broken off and left in the soil when the plants are pulled up, others will adhere to the roots and be buried with them. Such a system postulates a plant which will live and stand lopping for 2 to 3 years, according to the length of the pruning cycle. *Tephrosia candida* and, under up-country conditions, *Tephrosia vogelli*, are both suitable and several others will answer the purpose.

The question of whether more green material per acre can be obtained from trees or bush plants depends upon the planting distance in each case, but a very satisfactory weight of green

material per acre can be obtained from bush plants without unduly close planting. One superintendent has drawn attention to the usefulness of *Tephrosia candida* loppings for burying in holes dug for supplies. The establishment of supplies in old tea is seldom easy and burying a little green material in every hole has been found to assist the growth of young plants.

CHECK TO WEED GROWTH

Any shading of the ground will naturally act as a check to weed growth and bush plants will afford material assistance in this direction.

THE PROTECTION OF PLANT FOOD

In young tea clearings bush plants may take up a considerable amount of good material which, owing to the small area occupied by the roots of the tea plants, might otherwise leach out and be lost. Part of this plant food will later be returned to the soil in the loppings.

THE CHOICE OF A BUSH PLANT

The number of bush plants in use in tea cultivation for green manuring is not great and the choice again depends on conditions of climate and elevation and the principal object in view.

For the rapid production of a large quantity of green material *Crotalaria anagyroides* is, at suitable elevations, one of the best plants. Where it is desired to retain the plants for a longer period *Tephrosia candida* or *Tephrosia vogelii* are two of the most popular plants. The former has rather a longer life but the latter will produce more green material in the early stages. For contour hedges there is no more useful plant than *Clitoria cajanifolia*.

NOTES ON INDIVIDUAL BUSH PLANTS

Atylosia trinervia. Et-tora (Sinh.).—Anstead [2] records that this plant has been found useful in India for growing and digging in between tea. It is a much branched bush. There is no record of its use in tea in Ceylon.

Cajanus cajan. Dhall. Pigeon pea. Rata-tora (Sinh.), Thvarai (Tam.).—Bald [6] and Hope and Tunstall [21] report that this plant has been grown on Indian tea estates, treated in the same way as *Tephrosia candida*, but has not been found very satisfactory. Mann and Hutchinson [28] give a more satisfactory account though they state that definite figures are lacking. Only one Ceylon estate, in Wattegama, reports having tried

Cajanus cajan (Pigeon pea)

A contour hedge of *Clitoria cajanifolia*

Crotalaria anagyroides

the plant but without much success. At Peradeniya, dhall grown among young rubber died out after lopping and the quantity of green material obtained was small. More successful results are reported from dry or semi-dry districts but it is not thought that dhall can compare with *Tephrosia* and other plants for growing in tea. The seed pods are very liable to insect attack.

De Sornay [12] states that it prefers a semi-dry climate and will not stand much wind.

Cardamine hirsuta. Kaduku pillu (Tam.).—Anstead [5] states that this plant has been used in selective weeding on south Indian tea estates for the prevention of soil erosion.

Cassia hirsuta. Parangi-tora (Sinh.).—This plant was grown some years ago on the Experiment Station, Peradeniya, but as it was found that nodules did not form on the roots its cultivation was discontinued. It is, however, well spoken of in south India and has been grown on several estates in Ceylon. It stands lopping fairly well. It is not known if nodules are even found on its roots in Ceylon but if not there is no object in growing it where equally good plants which do form nodules are available.

Cassia mimosoides. Bin siyambala (Sinh.).—This plant has been grown on a tea estate in Dickoya. The superintendent reports that it is easy to establish from seed but dies off after seeding.

Clitoria cajanifolia.—This is a hardy, deep-rooted plant which, as far as information is available, appears only suitable for elevations up to about 2,500 feet. *Clitoria cajanifolia* is probably not suitable for a green manure or cover plant but is unsurpassed for contour hedges to check soil erosion. This view is supported by Bunting and Marsh [10].

Its deep-rooted habit enables it to weather severe droughts and to stand repeated hard lopping. Hedges of this plant at Peradeniya have been lopped repeatedly for over 5 years and show no signs of dying out. The few estates which have made use of the plant in this manner are enthusiastic over its merits.

The seeds are large and very sticky and this makes sowing difficult. It is said, however, that washing the seed impairs germination. For hedges seed should be sown thick, not more than 4 inches apart.

Crotalaria anagyroides.—This is the finest *Crotalaria* which has been tried at Peradeniya in the last ten years and its merits have been frequently referred to. Not a single tea estate,

however, reports having tried the plant although large quantities of seed have been sold. *Crotalaria anagyroides* will produce a large weight of green material in a shorter time than any other leguminous plant grown locally. The loppings have a high manurial value and decompose rapidly.

The plant stands lopping rather better than other *Crotalarias* grown at Peradeniya but it is unlikely that it will stand more than two loppings before dying out. *Crotalaria anagyroides* attains a height of about 8 feet in a year. The seed pods are very liable to insect attack.

Crotalaria Brownei.—The plant has been grown experimentally at Peradeniya. The leaves are large but the amount of foliage produced so far has been poor. A further trial is in progress.

Crotalaria incana.—This was one of the earlier *Crotalarias* tried in tea clearings at the Experiment Station, Peradeniya, but on account of its small size it cannot compare with *C. anagyroides* and others. Bunting and Marsh [10] report that in the F.M.S. the growth was poor and weak and it was found useless as a cover plant.

Crotalaria intermedia.—This has been grown experimentally at Peradeniya. The seed germinates very rapidly and evenly but the small size of the leaves and comparatively sparse foliage render it inferior to *C. anagyroides* and others.

Crotalaria juncea.—Sunn hemp. Hana (Sinh.), Shanal imappu (Tam.).—This plant has been very largely used for the green manuring of paddy, tobacco, and other crops in India. It is also cultivated for its fibre in south India and north Ceylon. As far as is known it has not been used for tea. If sown thickly it will produce a considerable quantity of green material in a short time. The growth at Peradeniya is inferior to that of *C. anagyroides*.

Crotalaria laburnifolia. Yak-beriya (Sinh.).—Hope and Tunstall [21] record that this plant has been tried in tea in India but was not found very successful. Wright [36] records its trial at Peradeniya but states that the yield of green material was low. The plant has been tried again more recently and this opinion is confirmed. The superintendent of a Balangoda estate on the other hand reports that it is one of the most promising green manure plants he has tried. There is just a possibility however that the plant was not *C. laburnifolia.*

Crotalaria longipes.—Seed of this plant was sent to Peradeniya by the superintendent of a Maskeliya estate who had

Crotalaria striata

received it from India. The plant has a spreading habit. All the plants died out after two loppings and the amount of green material furnished was not large.

Crotalaria semperflorens.—The superintendent of an estate at an elevation of about 5,000 feet gives a very favourable report on this plant and states that it forms a good protection against wind. It is stated to be grown on high tea estates in south India. It has not been tried at Peradeniya.

Crotalaria striata.—This plant was extensively used in the earlier green manuring trials in tea at Peradeniya. It has also been grown in tea both in north and south India, where, however, the plant is not very favourably spoken of.

Elliott and Whitehead [13] state that it grows freely in Ceylon up to about 3,000 feet and that 3 or 4 loppings can be taken before the plants die out. At Peradeniya as many loppings as this cannot be taken, but the life of such plants is usually longer at high elevations. Wright [36] gives the seed rate at 10 to 20 lb. per acre sowing in alternate rows, and states that in six months 12,000 lb. of green material per acre were obtained. He also states that in old tea at fairly high elevations little success was obtained unless the *Crotalaria* was sown after pruning and manuring. This is generally the best time to sow any green manure plant.

Willis [33] recommends 30 lb. of seed per acre and states that in four cuttings in a little over a year 20,827 lb. per acre of green material were obtained.

Bunting and Marsh [10] speak very highly of *striata* in the F.M.S. as a weed smotherer and source of green material. At Peradeniya both *C. anagyroides* and *C. usaramoensis* afford more green material and stand lopping better than *C. striata*. The plant is scarcely mentioned in the replies to the circulars. One estate in Dimbula reports that it was not very successful.

Crotalaria walkeri.—This plant has been grown experimentally at Peradeniya. Growth was fair but not very vigorous. The plants have a spreading habit. The recovery from lopping was fairly good.

Crotalaria usaramoensis.—At Peradeniya, this plant may be considered to come second to *C. anagyroides* among *Crotalarias*. Bunting and Marsh [10] describe it as producing the heaviest and quickest growth of all the covers under observation by them. It has been used on some tea estates for contour hedges but, being short-lived like all *Crotalarias*, it is not considered suitable

for this purpose. It has also been used by some estates at elevations between 3,500 feet and 5,200 feet as a source of green material. It, however, does not stand lopping well, and has not generally been recieved with much enthusiasm. The seed is very small and the seed rate is given by one superintendent as 2 to 3 lb. per acre. The seed pods are attacked by insects.

Galinsoga parviflora.—This is one of the plants stated by Anstead [5] to have been found useful in selective weeding on south Indian tea estates.

Desmodium gyroides.—Unlike most of the common *Desmodiums* in Ceylon this is a tall shrub attaining a height of 6 to 9 feet. It is described as the most useful of the many species of *Desmodiums* found in the Dutch East Indies where it is said to grow up to an elevation of 2,500 feet. Young plants are said to be liable to die off for some reason not yet satisfactorily explained.

At Peradeniya it grows well and furnishes a fair weight of loppings. It appears to die off, however, after lopping for 12 to 18 months.

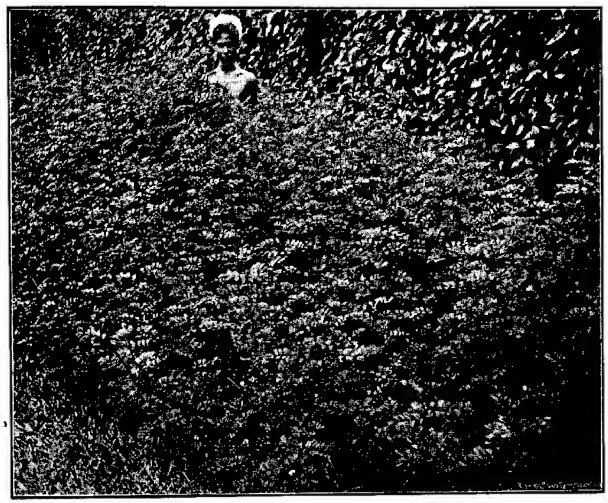
It has a profuse root system on which many nodules are found.

Indigofera arrecta.—This plant grows vigorously at Peradeniya but the weight of green material furnished is not large. It was tried for contour hedges in tea but after taking three loppings in 18 months the plants died out. A Dimbula estate, however, reports that it has survived lopping for three years. Other estates at about 4,000 feet have tried the plant but do not report very favourably. The plant seeds profusely from an early age. The seedlings are deep-rooted and are apt to overrun a field unless kept in check. *I. arrecta* is one of the plants from which indigo dye is obtained.

Indigofera hirsuta.—This plant has a more spreading habit and provides more leafly material than *I. arrecta*. It is, however, short-lived, its recovery from lopping is uncertain, and at Peradeniya it always appears to lodge after seeding. It forms a better protection for the soil than the more erect types.

A favourable account is given by Bunting and Marsh [10] who state that in the F.M.S. *Indigofera hirsuta* completely covered the ground in 4 months.

Indigofera suffruticosa.—The habit of this plant is rather more bushy than that of *I. arrecta*.



Indigofera hirsuta

Willis [33] records that the plant was sown in alternate lines in tea at Peradeniya. He gives the seed rate as 10 lb. per acre and states that the yield of green material was comparatively poor. The life of the plant is likely to be similar to that of *I. arrecta* to which it bears close resemblance.

Lupinus sp. Lupins.—Though very valuable for green manuring purposes in temperate zones lupins do not promise to achieve any great results in Ceylon. A number of varieties are now being grown at Peradeniya but at present the indications are that the climate is quite unsuitable.

A few tea estates have tried lupins. Only one estate, in West Haputale, at an elevation of 4,000 to 6,000 feet, has given a favourable report. Other estates at high elevations report serious damage by grubs, and one records a disease, *Pestalozzia lupini*.

The general indications are that the plant is not suitable for Ceylon.

Sesbania aegyptica. Chittakatti (Tam.).—This plant has been used for growing and digging in between tea in India.

It has been grown at Peradeniya where it yielded three cuttings of green material. The yield of loppings is, however, very meagre compared with many other plants.

Sesbania cannabina, Daincha.—This plant is referred to in many publications as *Sesbania aculeata* but as the name was changed to *Sesbania cannabina* a number of years ago at Peradeniya that name is here used.

Seed of this plant germinates with exceptional rapidity and evenness. It is very largely used for the green manuring of paddy in south India. It is hardy and will grow on a variety of soils, though it prefers a sandy one.

Hope and Tunstall [21] record that in tea seed is broadcasted at the rate of 15 to 30 lb. per acre They state that the crop grows very rapidly and can be hoed in two months later. In Assam an average patch of daincha was dug up and the weight of the complete plants was equal to 7,500 lb. per acre. Mann and Hutchinson [28] state that in one set of experiments the hoeing in of daincha resulted in larger increases in the yields of tea than with *Phaseolus mungo* or *Crotalaria striata*.

There is no doubt that when thickly sown and hoed in early daincha will provide a large quantity of organic matter, but this type of green manuring is but seldom practised in Ceylon and for lopping the plant is of very little use.

Strobilanthus viscosus. Nelu (Sinh.).—This wild plant grows prolifically in some up-country jungles and is quoted by Elliott and Whitehead [13] as a useful source of green material to be brought in from outside.

Several up-country estates record good results from the use of this green material.

Tephrosia candida. Boga medeloa.—This is probably the most popular and useful bush green manure plant in Ceylon from sea level to about 4,500 feet. If it has a rival it is *Tephrosia vogelii* but the latter plant is at present not so well known.

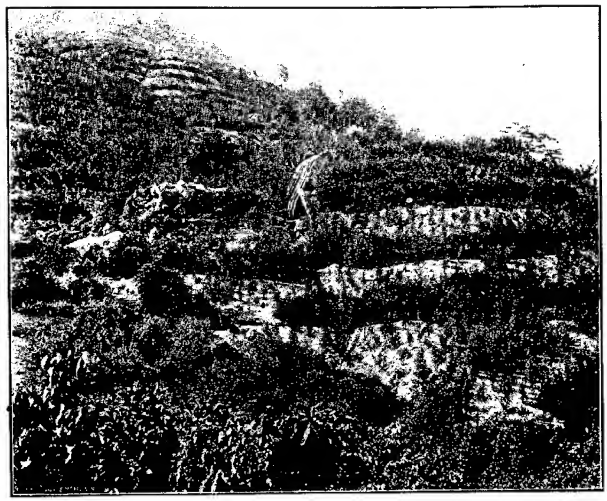
Bald [6] describes it as the most useful shrub for green manuring of tea in northern India. He states that the usual practice in India is to sow the seed with the early rains in alternate rows of tea. Three loppings a year are obtainable giving 7,200 to 8,000 lb. of green material per acre per lopping where the plants are spaced 8 feet by 4 feet. After about three years the plants are usually dug out and trenched in.

Hope and Tunstall [21] give the seed rate at 20 to 30 lb. per acre for sowing hedges in alternate rows. The authors add that the plants should be lopped as often as possible.

Mann and Hutchinson [28] recount the advantages of *Tephrosia candida* at length and state that the only disadvantages are interference with the working of the tea and red rust.

In Ceylon the plant is possibly used more for coconuts and rubber than for tea but it is considerably employed for the latter crop more particularly at low and medium elevations. Probably its greatest use is for contour hedges or hedges above drains and roads in clearings, and such hedges have undoubtedly done much to check erosion and at the same time furnish a considerable weight of green material.

In old tea the usual practice is to sow the seed in alternate rows. The general seed rate for this purpose is given at 4 to 6 lb. per acre though some estates use 10 lb. per acre and one recommends broadcasting 25 to 30 lb. per acre. Broadcasting is usually done, but one estate reports planting 20 feet by 20 feet interplanted with dadaps planted at a similar distance. In this case the bushes must be lopped and treated like trees. This is not thought to be the best way of using the plants. Some estates only plant *Tephrosia candida* in hedges above roads and drains while others plant it only in poor places where vacancies in tea have occurred. Once established there are two methods of dealing with the plants. One is to pull up and fork them in



Hedges of *Tephrosia candida* in a tea clearing

after 8 months to a year, and the other is to leave them for a number of years and lop periodically. The former practice is not general but some planters consider it to be the best method. The superintendent of a Matale estate considers that the plants should be left in only so long as they can be pulled up by hand. The cost of pulling the plants and forking them in within a year is given as from Rs. 7·50 to Rs. 10 per acre.

Where regular lopping is done two to three loppings a year can be taken. The cost of lopping alone is given at various figures between 60 cents and Rs. 2 per acre. The age at which *Tephrosia candida* should be finally dug out must vary with the elevation. At low and medium elevations the plant will have become very woody and the yield of green material will have sensibly diminished after three years. At high elevations the plant can be economically retained for from four to six years.

The ability to grow on poor soil is one of the most valuable characteristics of the plant. There is considerable evidence of improvement to tea as the result of planting *Tephrosia candida*.

The pests and diseases to which the plant is prone are somewhat numerous; it is often severely attacked by shot-hole borer and some superintendents consider that its presence results in increased incidence of this pest. Several scale insects including *Pseudococcus virgatus* attack the plant more or less severely. The seed pods are attacked by a number of insects and good seed is often hard to obtain. Various fungoid diseases, including *Fomes lignosus* and *Poria hypobrunnea* are found on old plants, but such diseases will not be common if the plants are not left in too long.

These drawbacks, however, have done little to diminish the popularity of the plant which is still the most widely grown of any bush plant in Ceylon.

Tephrosia noctiflora. Ela-pila (Sinh.).—This plant was formerly known as *T. hookeriana*. It is much smaller than *T. candida* or *T. vogelii* and given similar conditions will not furnish more than a quarter of the green material that could be obtained from them. It has rather a low-spreading habit. It is possibly rather more hardy than *T. candida* but in other respects cannot be compared with it.

Tephrosia tinctoria. Alu-pila (Sinh.).—Anstead [3] records that this is the commonest wild legume found growing on some tea estates in the Wynaad and if encouraged will form an excellent light cover. It has a low-spreading habit.

Tephrosia senticosa.—This is a low-spreading shrub which has been grown experimentally at Peradeniya. It is of little use as a source of green material, and as a ground cover more suitable plants are available.

Tephrosia villosa. Bu-pila (Sinh.).—This plant has been grown experimentally at Peradeniya. It has been seen in a nursery in Dimbula but the yield of green material promised is not large.

Tephrosia vogelii.—This plant shows a considerable resemblance to *T. candida* but is easily distinguished by its pods which are larger, longer, and very hairy. The leaves are also larger and the foliage generally more luxuriant. It yields a larger quantity of green material when young than *T. candida* but its life is shorter. At Peradeniya it does not generally live for more than two years, but in Dimbula, where it grows very well, it appears to last for a number of years and stands lopping well. Burnett [11] records that it grows well in Dickoya but is inclined to grow out over the surface of the tea bushes and interfere with the plucking. The same however may be said of *T. candida*, though possibly to a less extent, and the more luxuriant foliage of *T. vogelii* is in other respects a point in its favour. Another advantage is that as far as is known the seed pods are not liable to insect attack. Good accounts have also been received of the plant from Kalutara and Balangoda.

Tithonia diversifolia, Wild Sunflower. Natta suriya (Sinh.), Suriyakandu (Tam.).—This plant is not leguminous but its prolific growth on waste land at low and medium elevations renders it a most useful source of green material. It was used in an experiment at Peradeniya in which green material brought in from outside was buried, and was found to result in as great an increase in nitrates in the soil as was obtained from the green material of leguminous plants.

GROUND COVER PLANTS

The uses of ground cover plants differ somewhat from those of trees of bush plants and it will be desirable to set out afresh the advantages to be gained:

(1) The soil is shaded.

(2) The root action of the ground cover plants helps to open up the soil and aids the absorption of rain water.

(3) If a leguminous plant is used the other advantages enumerated can be obtained without depleting the supply of nitrogen in the soil and an increase of nitrogen may possibly result.

(4) Soil erosion is effectively checked.

(5) In spite of increased transpiration there is evidence to show that in regions of sufficient rainfall more moisture may eventually be retained in soil under a ground cover.

(6) An increase in the organic matter in the soil may be expected to result even if the cover is not turned in, while an added increase may be expected if the creeper is buried or forked in.

(7) Weed growth is checked.

(8) In a young clearing, plant food which might otherwise have been lost is retained for future use.

These advantages will now be discussed in greater detail.

(1) *Shading the Soil.*—The advantages of shading the soil in a tropical climate have already been explained. A ground cover plant will achieve this object more effectually than a tree or bush plant, provided the growth is good.

(2) *Root Action.*—The root action of ground cover plants will naturally not extend to the same depth as that of trees or bush plants. The mass of rootlets afforded by such a cover plant as *Indigofera endecaphylla*, however, will permeate the surface soil more effectually than the roots of trees or bush plants could do.

(3) *Nitrogen Assimilation.*—All that has been said in this connection with regard to trees or bush plants will hold good for ground cover plants. Two sets of Peradeniya figures can be quoted in the matter of gain or loss of nitrogen when the plant is not turned in. In the trials of *Indigofera endecaphylla* in old tea on the Experiment Station, Peradeniya, soil analyses are made by the Agricultural Chemist every two years, just before pruning. The *Indigofera* was planted after pruning in October, 1925, and the average nitrogen contents of all the plots under treatment has been as follows:

1925	1927	1929
·096	·087	·098

It will be seen that a slight decrease occurred at the end of the first two years while at the end of four years a slight increase was registered. The full results of this trial will be found in two articles, one by the writer, and one by Dr. A. W. R. Joachim, Agricultural Chemist, in *The Tropical Agriculturist* of March, 1930.

Another set of figures has been published by Joachim and Panditteseker [24] in connection with a further experiment at Peradeniya, and these have been quoted in connection with trees and bush plants. In this case the samples were taken from undisturbed plots of *Dolichos Hosei* (Vigna), and the indication is that large increases of nitrogen cannot be expected from growing cover plants without turning them in periodically.

(4) *Check to Soil Erosion.*—In Ceylon this will usually be the principal object in planting a ground cover, and such a crop is the only really effective method of preventing the movement of surface soil, or minimising it to the utmost. Figures of a soil erosion experiment, being conducted at Peradeniya, have already been quoted in Section I. The evils of soil erosion are so well known and the beneficial effect of a ground cover in checking erosion so obvious that it appears unnecessary to discuss the matter further.

(5) *Soil Moisture.*—This is a most important consideration. The loss of soil moisture through transpiration appears at first sight to constitute a considerable drawback to the planting of a cover crop in tea. Before coming to any conclusion in this matter however, it will be necessary to examine the opinions and experience of other authorities and estate superintendents.

Hope and Tunstall [21] write "The soil is always losing moisture by evaporation on the surface; but at the same time the plant by transpiration is losing moisture also and it is found that in the cases investigated the amount of water lost by transpiration considerably exceeds the amount saved by the reduction in the evaporation from the soil surface". This view is generally supported by experiments elsewhere. The results of Ceylon investigations and experience, however, are generally more favourable to the cover crop, at all events after the latter has been in possession of the soil for some time. The matter has been already dealt with to some extent in Section I and the results of the investigations at Peradeniya into this aspect of cover crops may be summed by quoting from Joachim and Kandiah [23] "Soils planted with cover crops either cut or left uncut are found to retain more moisture than bare soils at nearly all depths up to 24 inches. The results of previous work on the subject are therefore confirmed". Turning to field experience it may be stated that tea under *Indigofera endecaphylla* at Peradeniya has never shown any sign of being more adversely affected by a drought than clean-weeded tea, in fact the impression gained has been the reverse. At Peradeniya, young

supplies come on better in a cover of *Indigofera* than on clean weeded land. A Ratnapura estate has reported that *Indigofera* has been a great success in young clearings and has had no adverse effect on the young tea plants. Similar reports have been received from Bandarawela and Moneragala which are dry districts. On the other had two estates in Badulla have reported unfavourably of *Indigofera* in young clearings and one superintendent states this cover to be "definitely injurious" to young tea. It is probable that if there was an adverse effect it was due to undue absorption of moisture at the expense of the tea plants. Hope and Tunstall's remarks refer to Indian climatic conditions which are very different to those of Ceylon. There is no concrete evidence in Ceylon of any adverse effect caused by a cover crop in old tea, but opinions as to young clearings seem somewhat divided. Generally the principal object of planting a cover crop in a clearing is to save soil erosion which will naturally be most severe in the first two or three years. If the land is steep and no other special measures have been taken the necessity of checking erosion seems so urgent that the planting of a cover crop would appear generally advisable. It will always be necessary to keep a clear space round young tea bushes and it is thought that if in drier districts this clearing is done in a somewhat larger ring the adverse effects complained of may not be felt.

(6) *Increase of Organic Matter.*—This aspect of the practice of growing ground cover plants among tea has received far more attention in India than in Ceylon. The principal reason of this is probably that a considerable amount of tea in nothern India is grown on comparatively flat land and on such land the practice of growing an annual leguminous ground cover crop and hoeing it in a few months can be adopted with benefit. For many Ceylon estates the erosion resulting from such a practice would probably more than counterbalance the benefit. It is thought, however, that by substituting envelope-forking for hoeing the practice of growing a ground cover crop to be incorporated later in the soil might be considerably extended. In spite of the difference of conditions it will be advisable to examine Indian practice and opinions in this matter.

Bald [6] after discussing the use of trees and bush plants gives it as his opininon that more rapid results can be obtained by sowing an annual crop between the lines of tea bushes, and further states that a green manure crop has reached its maximum usefulness when it has begun to flower and should then be hoed in. The possibility of soil erosion is not neglected for the author

states that on steep hillsides "It is madness to dig during the rains", and in such cases the crop is merely sickled and left on the ground. By actual experiment the author claims to have noted an increase of fully 70 lb. of tea per acre on a hill estate at an elevation of 4,000 feet by this practice of green manuring and he states that the increase in the plains must be more.

Hope and Tunstall [21] describe *Phaseolus mungo* (a creeping leguminous plant) as the most satisfactory green manure at present known for replacing lost organic matter in tea land.

Mann and Hutchinson [28] in discussing the hoeing in of *Phaseolus mungo*, state that the effect on yield of tea appears to commence about three weeks after the hoeing in of the green crops. The importance of obtaining a quick growth of the creeper, is stressed and it is stated that the crop should not occupy the land for more than 6 to 8 weeks.

Conditions in different parts of India of course differ largely but it is gathered that, speaking generally, in northern India trees in tea are usually not lopped and reliance is placed on annual creeping legumes for the replenishment of organic matter. In Ceylon on the other hand the loppings of trees are the chief source of organic matter while, ground cover crops, if used at all, are planted principally with the object of checking soil erosion. Each country must suit its own needs but it is thought that the improvement in the physical texture of the soil and the increase in organic matter likely to result from the growing of a cover crop, even if it is not turned in to the soil, is not always realised. In the trial of *Indigofera endecaphylla* in progress at Peradeniya the following percentages of organic matter were found after planting *Indigofera* in 1925:

	1925	1927	1929
Average percentage of organic matter	3·75	4·56	5·29

There is little doubt that these increases would have been larger if the creeper had been periodically forked in and this question will probably be the subject of the next trial. The question of erosion must always be considered along with the proposals to fork in a cover crop and it is gratifying to note than even without digging in the cover an increase in organic matter can be confidently expected.

A good many Ceylon tea estates have inaugurated a system of digging or forking in cover crops in order to obtain the maximum increase of organic matter. The information furnished by estates relates almost entirely to *Indigofera endecaphylla*. Some estates cut and fork in this creeper, others

fork it in without cutting. Costs of cutting and forking in are given as being between Rs. 4·80 and Rs. 5 per acre. One estate cuts the creeper at manuring, throws it in to the next row and forks it in at a total cost of Rs. 7·50 per acre. It may be mentioned that there is no difficulty about forking through the creeper without cutting it out but experience shows that it is difficult to incorporate any considerable quantity of green material without first cutting the creeper.

(7) *A Check to Weed Growth.*—This is a controversial subject. Some planters assert that once a satisfactory cover is established weeding is a thing of the past, while others assert that the presence of a cover crop increases the difficulty and cost of weeding.

There are two aspects of weeding in connection with a cover plant, one is the removal of the plant itself from the tea bushes—a weed is a plant in its wrong place, and if a cover plant is creeping over a tea bush it becomes a weed—and the other is the effect of the cover plant on other weeds. If the cover plant needs so much controlling that the labour involved more than counterbalances any saving in the removal of other weeds there is obviously no advantage gained as regards the weeding bill. The remedy is to choose a suitable plant. In the case of the best known cover plant for tea in Ceylon, *Indigofera endecaphylla*, the creeper does not twine round or climb up a tea bush; it will sometimes grow up through the middle of the bushes but is very easily removed by hand. Writers on green manuring of tea in India allude to the efficiency of soya bean (*Glycine hispida*) and of *Phaseolus mungo* in keeping down weed growth, but also mention the difficulty of preventing these plants from climbing up the bushes.

Figures are not available, but it is considered that in the case of *Indigofera endecaphylla* though the cost of weeding will be increased in the first year, thereafter it should gradually drop below the normal. At Peradeniya very few weeds, except couch grass, come through *Indigofera*. Cora will appear if the cover is removed, even if it has been apparently smothered for two or three years. It is not likely that a cover crop will ever enable weeding to be dispensed with altogether.

Little information is available about the effect of weeding of creepers other than *Indigofera endecaphylla*. *Dolichos Hosei* has been used in tea and it is thought that the cost of keeping this plant from smothering the bushes is not excessive. The subject will be mentioned again in the notes that follow.

(8) *Retention of Plant Food.*— By its nature and habit a ground cover plant is better fitted to take up plant food which is not within reach of the root system of young tea than a tree or bush plant. This plant food will thus be retained on the land and some will later be returned if the creeper is dug or forked in, and by the natural leaf-fall.

THE CHOICE OF A GROUND COVER PLANT

A certain amount has been said on this subject in discussing the question of weeding. Perhaps the principal requirements of a cover plant for tea is that it should not climb over or unduly interfere with the progress of coolies. *Indigofera endecaphylla* fulfils these requirements better than any other plant that has been planted in tea in Ceylon. This creeper will thrive from sea level up to about 5,000 feet. It is not known whether any suitable creeper has been found for higher elevations than this. Next in popularity probably comes *Dolichos Hosei* but this creeper cannot be said to be extensively planted as a cover for tea.

These remarks refer only to planted creepers; selective weeding will be discussed later.

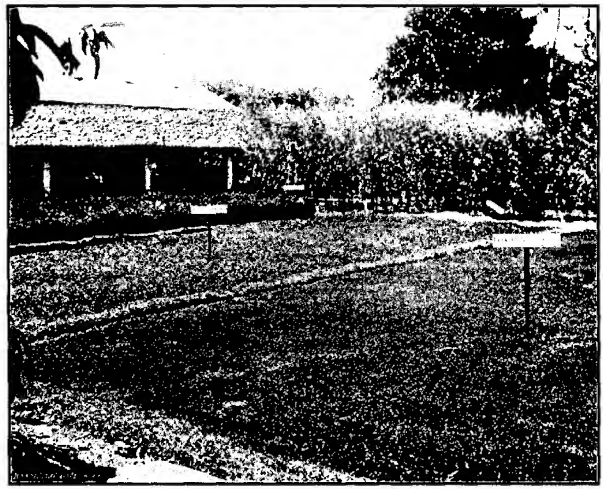
DISADVANTAGES OF A GROUND COVER IN TEA

The question of the smothering of tea bushes and undue absorption of moisture have already been dealt with. There remains the harbouring of snakes and leeches. At Peradeniya snakes have been fairly frequently found among *Indigofera endecaphylla*. Two pluckers have been bitten in four years though fortunately the results were not serious. There would seem to be no way of avoiding this disadvantage which is possibly the most serious objection to the planting of a ground cover in tea.

In *Indigofera* very few complaints of leeches have been received. The superintendent of one estate which has about 50 acres under *Indigofera* reports that leeches are never found in this creeper though they abound in the district. At Peradeniya a good many leeches were found after the heavy rains in November 1929. Previous to this they had been very little noticed.

NOTES ON INDIVIDUAL GROUND COVER PLANTS

Centella asiatica. Gotukola, Hin-gotukola (Sinh.), Kalluvallarai (Tam.).—This plant was previously identified as *Hydrocotyle asiatica*. It is found growing vigorously in tea on many estates. Its value appears to be a matter of controversy.



Desmodium triflorum and D. heterophyllum

A superintendent at Kalutara describes the plant as a pest and states that large sums of money have been spent on its eradication. On the other hand a superintendent in the Kelani Valley considers that it gives a more desirable cover than Vigna, both for tea and rubber, but is hard to establish.

For a general opinion as to the encouragement of such plants the reader is referred to the later heading "Selective Weeding".

Cotula australis.—Anstead [5] states that use has been made of this plant in selective weeding for the prevention of soil erosion on south Indian tea estates.

Desmodium triflorum. Hin-undupiyali (Sinh.), Serupilladi (Tam.).—This is a very small, close-growing, perennial herb, indigenous to Ceylon found up to about 2,000 feet. It has probably never been planted in tea, but in some cases it has been encouraged to grow by selective weeding. Emphatic reports of its unfavourable effect on young tea have been received. Burnett [11] states that its matted root growth appears to prevent soil aeration and to affect the tea detrimentally.

Evidence generally points to the close matted growth formed by the plant as its chief disadvantage. It is thought that if forking through the cover was regularly done the ill-effects might be mitigated, but as the plant's only advantage appears to be that it grows spontaneously there seems to be no adequate reason for recommending it.

Dolichos Hosei (Vigna).—This plant was for some years known as *Vigna oligosperma* and the term "Vigna" is almost accepted as a common name. The creeper is principally grown as a cover crop in rubber but has been planted to some small extent in tea.

Grigsby [15] points out that it thrives well in some places while in others it will not grow at all; in fact on some estates it is almost impossible to establish. When difficulty is found in establishing it a small application of a general mixture, rich in phosphates, is recommended. The author recommends starting nurseries from seed or cuttings so that fresh runners are available for planting out in the field. It is necessary that every runner planted out should contain a small root. This precaution has been found at Peradeniya to make all the difference between success and failure. Vigna usually grows downhill so that it is advisable to put the ends of the runners going downhill. Some estates report, however, that sowing seed in the field is more successful than runners.

On tea estates a number of trials have been made with Vigna from sea level up to 5,000 feet. The great objection to the use of this creeper in tea is that it is liable to creep over and smother the tea bushes. It is not, however, a very strong climber and it is thought the expense of keeping it off the bushes is by no means prohibitive. One or two estates have given up Vigna in tea on account of its climbing proclivity. An up-country estate reports that the creeper is delicate and is frequently attacked by caterpillars. It has been reported that the cost of weeding is reduced by the establishment of Vigna. An estate in the Agra Patanas at an elevation of 4,500 to 6,600 feet reports that the creeper is well established and no further weeding is necessary. *Dolichos Hosei* certainly forms a possible cover crop for tea but *Indigofera endecaphylla* is to be preferred.

Dolichos biflorus, Horse gram, Kollu (Sinh. and Tam.).—Mann and Hutchinson [28] report that this creeper has been particularly successful on one estate in India as a green manure for tea. It is not a perennial, however, and in India is grown for early hoeing in. It is a strong climber and for this reason cannot be considered really suitable for tea.

Drymaria cordata. Kukulu pala (Sinh.), Patani pillu, Kadalai pillu (Tam.).—This indigenous creeper is, like *Oxalis*, found growing prolifically on some up-country estates. It is recorded in Kotmale, Dimbula, and Dickoya, but is probably found also in other districts. It is liable to climb up bushes and particular care must be taken to keep it off young supplies. Superintendents have been faced with the problem as to whether to encourage it or attempt its eradication and as regards the solution of this problem the reader is again referred to the later heading "Selective Weeding".

An estate in Dickoya reports that weeding among *Drymaria* is very difficult.

Glycine hispida. Soy bean. Soya bean.—Hope and Tunstall [21] record that a number of varieties are used for the green manuring of tea in the Darjeeling districts of India. It is usually sown broadcast in alternate rows immediately after hoeing. A seed rate of 80 lb. per acre is mentioned. At Tocklai the plant was found to do best in shady places. The plant is reported to be very effective in keeping down weeds and in preventing soil erosion.

A white-seeded variety is reported to have made good growth at Peradeiya but on another occasion the crop was almost completely destroyed by Kalutara snails.

Indigofera endecaphylla as a cover crop for tea

Like *Dolichos biflorus* the soy bean is an annual and is moreover a strong climber.

Indigofera endecaphylla.—For some years this creeper has been considered at Peradeniya to be the best cover plant for tea of any so far tried. Possibly its principal advantage is that unlike Vigna and many other creepers it will not climb over tea. At Peradeniya 14 plots of tea comprising in all 8 acres, have been under this cover crop since 1925. For the period between the 1927 and 1929 prunings, in spite of short rainfall and the loss of a number of bushes after the 1927 pruning, there was a general increase of yields of tea over the 1923-1925 period. There was also a satisfactory increase in the nitrogen content of the soil, and a most marked increase in organic matter, amounting to nearly 40 per cent.

Indigofera endecaphylla flourishes in Ceylon from sea level up to about 5,000 feet. An estate at Pundaluoya reports that cuttings did not strike at 5,300 feet, struck fairly well but grew slowly at 4,100 feet, and was easily established and grew rapidly at 3,400 feet. Another estate reports definite failure at 6,000 feet.

Alexander [1] says that in south India its natural habitat is 3,000 feet, but that it thrives well at altitudes varying from sea level to 6,000 feet. He adds that the creeper gives a heavier mulch than any other cover plant and protects the soil most efficiently from sun and erosion.

The plant is best propagated in the field from cuttings; seed in the fields has not been found successful. At Peradeniya two or three 18-inch cuttings were planted together, the middle of the cuttings being buried leaving both ends out. Such bunches of cuttings were put in 2 feet apart, but wider spacing can be adopted if an early cover is not of urgent importance. A fair cover was formed in 6 months and a continuous even cover in a year from planting.

The first object at Peradeniya has been to test the effect of the mere presence of the creeper on the tea, but there is little doubt that more benefit can be obtained by forking or digging it in. Some estates cut and fork in the creeper at a cost of from Rs. 4·80 to Rs. 5 per acre. An estate in Kalutara cuts and buries the creeper in holes at a similar cost. On another estate the creeper is cut at manuring time, the green material thrown into the next row and there forked in at a cost of Rs. 7·50

per acre. Some estates report that the creeper is forked in without cutting. There is no difficulty about forking through the creeper but experience shows that it is not at all easy to incorporate any considerable amount of the creeper in the soil without first cutting it.

Indigofera endecaphylla is remarkably free from pests and diseases. Light [25] reports that the only pest of importance is a caterpillar, *Dichomeris ianthes*, which sometimes completely defoliates the creeper. Experience at Peradeniya, however, is that the creeper recovers very quickly from such defoliation. The use of this creeper in young clearings has already been dealt with at some length in discussing the question of loss of moisture. Opinions on this matter are divided: generally in the wetter districts reports are favourable while in districts subject to long droughts some adverse reports on its effect on young tea have been received. One estate complains that it grows too high for the young tea but any cover crop needs keeping away from the immediate proximity of young tea plants and *Indigofera* should give less trouble than most others in this respect.

In old tea reports are more favourable though the plant has by no means achieved universal popularity. The danger of snakes has already been mentioned.

An examination of the physical condition of soil which had been under *Indigofera* for some time compared with clean-weeded soil will convince the most sceptical that improvement is taking place, and analysis bears that out.

When once a good cover is established a reduction in weeding costs may be anticipated though weeding can never be dispensed with. Couch grass comes through the creeper at Peradeniya, and *Mycania scandens* and a convolvulus creeper have given some trouble.

There is little doubt that *I. endecaphylla* has come to stay.

Oxalis corniculata. Hin-embul-embiliya (Sinh.), Kotti puliari (Tam.).—This species of *Oxalis* does not form bulbs in the same way as do the others mentioned; it is therefore quite easy to control. It is a small close-growing indigenous creeper with a yellow flower. It is not leguminous.

Anstead [5] mentions it as a useful plant in selective weeding on south Indian tea estates that hundreds of acres of steep tea land are under *Oxalis*. He adds that the yields of tea have

been maintained and in fact increased and the effect on the tea in the hot weather is very slight.

The plant was left unweeded in the tea plots at Peradeniya for about two years and formed a fair but patchy cover. It was not found to be a strong enough grower to keep down other weeds, and grasses grew freely through it. Without cultivation this cover might be open to the same objections as *Desmodium triflorum*. Only one estate mentions this plant and the superintendent says that *O. cornuculata* dies off in dry weather but provides a fair amount of organic matter.

Oxalis corymbosa. Puliari pillu (Tam.).—This plant is rampant on many up-country tea estates and was formerly regarded as a noxious weed. Drastic and expensive efforts were made to eradicate the plant but owing to the bulbs which formed below ground these efforts generally resulted in a thicker growth. It then began to be thought that on a steep land the plant might do more good than harm. Efforts to eradicate this weed gradually ceased and there are now actual instances of the planting of *Oxalis*. The plant dies down once a year in the hot weather and this is a great safeguard against it absorbing too much mois ture at the expense of the tea.

Wilkinson [32] quotes an example of a very steep field where a prolific growth of *Oxalis corymbosa* has existed for 20 years. He shows by a graph that the yield of this field has throughout been satisfactorily maintained compared with the general average of the estate.

Superintendents in other estates in Dimbula, Dickoya, and Gammaduwa report that they do not consider *Oxalis* at all harmful and the yield of tea is not reduced by its presence.

Oxalis latifolia. Puliari pillu (Tam.).—This plant grows freely in Dimbula and other up-country tea districts and is often found mixed with *O. corymbosa*.

Oxalis violacea. Puliari pillu (Tam.).—Remarks made with regard to *O. corymbosa* would appear to apply equally to *O. violacea*.

Parochetus communis.—This is an indigenous creeper which has been found growing on several up-country estates and is highly spoken of.

Petch [29] says that it occurs in Ceylon from an elevation of 4,000 feet upwards being frequently met with on shady banks round Nuwara Eliya.

Anstead [6] says that it has been used in selective weeding in south India but that it is not easy to establish over large areas. It dies back in the dry weather but comes on again with rain.

Attempts to establish the plant at Peradeniya have so far failed.

Phaseolus mungo. Green gram. Mun-eta (Sinh.), Pasipayiru (Tam.).—Hope and Tunstall [21] state that a number of varieties are used for green manuring of tea in India. These are distinguished by the colour of the seed which varies from white to black. The authors state that both experiment and practical experience of planters have proved the value of the plant without doubt. They add that its twining habit is a disadvantage. A good crop is stated to give 8,000 lb. of green material per acre. It is said that the crop will not grow satisfactorily on poor soil without manure.

Mann and Hutchinson [28] give a seed rate of 40 lb. per acre.

The plant is attacked by several caterpillars. It is an annual and is grown only for hoeing in and not as a permanent cover crop.

It is not quite certain whether the numerous references in Indian literature are to the green gram only or whether they include the black gram. Both have been called *Phaseolus mungo*. In any case the growth of the two plants is similar. At Peradeniya the black gram (Sinhalese Undu and Tamil Ulundu) is the stronger grower of the two.

Vigna sinensis. Cow pea. Mekaral (Sinh), Paithankai (Tam.).—This plant is well known as a food crop in Ceylon but has not been used to any extent as a green manure in tea. Willis [33] reports that cow peas were not found very successful as a green manure for tea.

Again *V. sinensis* is an annual and is only suitable for digging in. Thick sowing is necessary to obtain a good cover.

MISCELLANEOUS PRACTICES

In addition to the planting of trees, bush plants, and creepers in tea there are a number of practices which deserve mention in this section.

SELECTIVE WEEDING

In effect there is little difference between allowing a plant which has appeared spontaneously to grow and planting it,

except that the choice of a plant is limited to those found on the land. Plants thus allowed to grow in tea are usually the low-growing kinds that would come under the heading of ground covers, but occasionally bush plants are allowed to grow up."

Anstead [3] describes an experiment in a tea clearing in the Wynaad district in which all legumes were allowed to grow. The commonest were found to be *Tephrosia tinctoria* and *Cassia mimosoides*. A good leguminous cover was obtained at practically no cost. On another estate *Tephrosia tinctoria* and *Crotalaria nana* were found to be the commonest wild legumes.

In another publication [5] the same author reverts to this subject in connection with the prevention of soil erosion. He says that a plant which will not climb is desired. The ideal plant is hard to find but *Cassia mimosoides* comes nearest to it. He mentions also *Parochetus communis* as a useful native legume but says it is not so easy to establish and dies down during the hot weather. Where a leguminous plant is not available he recommends the encouragement of *Oxalis corniculata* and states that many hundreds of acres of tea are under this weed, the tea has been decidedly benefited and erosion is practically nil. Other plants are also mentioned.

"In Ceylon the practice of selective weeding is perhaps not very widely adopted and is generally confined to one or two well-known plants. The most common are undoubtedly the species of *Oxalis* found in up-country tea districts. In early days strenuous efforts to eradicate these plants were made but with little success and with an undoubted increase in soil erosion. These expensive attempts were gradually abandoned, principally no doubt at first on account of their ineffectiveness. The realisation then gradually dawned that *Oxalis* undoubtedly helped in checking soil erosion and in this way possibly did more good than harm. This view gradually gained ground and today there are instances where the planting of *Oxalis* on tea estates has been undertaken.

Wilkinson [32] gives an interesting account of his experience with *Oxalis* in which he furnishes figures to show that a steep field covered with *Oxalis* has maintained its yield satisfactorily while a considerable amount of soil erosion has been saved.

Bamber [6], writing in 1915, recommends leaving *Oxalis* if once established. He points out that scraping will only increase the thickness of the subsequent growth and that the plant in any case dies down almost entirely at the beginning of the dry season. He is of the opinion that if tea is properly manured the yield is not likely to fall on account of the presence of *Oxalis*.

It is now the considered opinion of the Department of Agriculture that the species of *Oxalis* found on up-country tea estates are probably more beneficial than harmful to tea.

Another plant commonly found in tea is *Centella asiatica* (*Hydrocotyle asiatica*) better known under its Sinhalese name of Gotukola. Opinions appear to differ as to the desirability of this plant in tea. Two Kalutara estates say that it has proved a pest and that large sums have been spent on its eradication while the superintendents of two estates in the Kelani Valley consider it a better cover for both tea and rubber than Vigna but complain that it is hard to establish.

Another plant which has recently been the subject of a good deal of correspondence and discussion is *Drymaria cordata*. This plant is very prolific on some up-country estates and is sometimes found mixed with *Oxalis*. There is at all events a probability that on steep slopes it will do more good than harm. Care must be taken to keep young supplies clear of the plant as unlike *Oxalis* it will creep over the bushes.

Another plant which has been the subject of experiment in selective weeding is *Desmodium triflorum*. In this case the evidence is almost unanimously unfavourable. Probably the ill-effect of the plant on tea is due to the close mat it forms and possibly if forking through the cover were practised the effect might be different.

The whole question of selective weeding is one on which it is impossible to lay down hard-and-fast rules. Specimens of plants found growing among tea are often sent to the Department with an enquiry as to whether the plant will "do harm to the tea". Unfortunately plants cannot be classified into those harmful or beneficial to tea. The pros and cons must be considered in each case. The pros are, in the case of a leguminous

plant, all the advantages of planting creepers in tea which have been enumerated. In the case of a non-leguminous plant, all the advantages hold good except the assimilation of atmospheric nitrogen by the plant. The cons are the well-known objections to "weeds", the absorption of plant food and moisture, possibly at the expense of the tea plant, and in the case of a close-growing plant interference with soil aeration. A further practical, though not very serious, difficulty is that of training labour to leave only the plant or plants desired and the possible increase in weeding costs entailed.

Of the advantages of planting a creeper in tea probably the checking of soil erosion will generally be the most potent factor in favour of some form of selective weeding.

It may be mentioned here that the toxic effect of grasses on fruit trees which was claimed to have been proved at the Woburn Experiment Station is not upheld by modern investigators. The detrimental influence of grass is generally accepted but the toxic action is disputed and it is held that the effect is due to physical causes such as lack of aeration.

The only safe general advice that can be given as regards the encouragement of any particular plant in tea is to make a trial with the plant and watch the effect on the tea, with the important proviso that definite patches or strips should be kept clean weeded as controls.

THE USE OF OUTSIDE GREEN MATERIAL

Such material may be obtained from jungles or other uncultivated portions of an estate. This practice has one great advantage over green manuring with plants grown in the tea itself; all the nitrogen and mineral matter contained in the material has been obtained from outside and is consequently pure gain. The cost of cutting and transport will in most cases form the limiting factor for this practice. Once the green material has been brought on to the land it may be disposed of in any of the ways already described. Elliott and Whitehead [13] mention the large quantity of green material which can be obtained from undergrowth in jungle adjoining estates, particularly where Nelu (*Strobilanthus viscosus*) is abundant.

Hope and Tunstall [21] also draw attention to this means of obtaining green material and point out that it is not necessary for the green material to be obtained from leguminous plants.

This point needs emphasis; the leaves of leguminous plants are not necessarily richer in nitrogen than those of non-leguminous plants and green material obtained from the latter may be just as valuable. In an experiment at Peradeniya it was found that burying the leaves of the wild sunflower, *Tithonia diversifolia*, resulted in just as great an increase of nitrates in the soil as the burying of leaves of leguminous plants. The wild sunflower grows prolifically in waste places in proximity to many mid and low-country estates and forms a valuable source of green material.

Material brought in from outside is often merely mulched on the surface, or is first mulched and later forked in. Two estates, one in the Welimada district and one in the Uda-Pussellawa, both dry districts, report that mana grass from patanas which is used for thatching is later forked in when it has rotted. Considerable benefit to the tea is reported to result from this procedure.

Bamber and Holmes [9] report a marked improvement in the yield and appearance of tea from the application of a heavy mulch of green jungle material and tea prunings.

THE BURYING OF TEA PRUNINGS

Elliott and Whitehead [13] point out that the burying or forking in of tea prunings is a routine operation on nearly all Ceylon tea estates and that this operation contributes towards the maintenance of the necessary supply of organic matter in the soil. As in the case of other green material if the prunings are allowed to dry considerable losses in the value of the material are sustained. The burying of green tea prunings, however, involves the lopping off of the green leaves and small twigs immediately after the pruning and this work involves a good deal of expense. For this reason a common practice is to pile the prunings into alternate rows till the leaves drop off, then transfer the woody portion of the prunings to the next row and fork in the dried leaves, often in conjunction with the application of a pruning mixture.

COFFEE

THE cultivation of coffee in Ceylon is mostly confined to the growing of the Robusta types by small holders, although these types are found on a larger scale on a few estates.

Very little information is available on the green manuring of this crop in Ceylon. The subject may conveniently be dealt with, as before, under the headings trees, bush plants, and ground covers.

TREES

The advantages of planting trees in coffee are similar to those obtaining in tea. Each of these will now be discussed in detail.

SHADE

The provision of shade for coffee is considered highly desirable if not essential in almost all countries.

Ukers [31] writing of Arabian coffee says "It requires shade when it grows in hot low-lying districts; but when it grows on elevated land it thrives without such protection".

Anstead [4] affirms the necessity of growing coffee under shade in south India, and adds that a tree should be chosen which will not lose its leaves during the hot weather. He mentions also the necessity of careful lopping in order that the shade may not become too dense.

A correspondent to an Indian journal states that the sole disadvantage in shading coffee is the reduction in yield and that coffee grown without shade will bear larger crops but live for a shorter time than shaded coffee.

There appears to be a much stronger case for the necessity of actual shade in coffee than in tea.

The first necessity is the provision of temporary shade for the young coffee plants. If artificial means are not used such shade is most easily provided by the planting of quick-growing leguminous plants of the bush type round the young coffee plants.

At the Experiment Station, Peradeniya, almost all the coffee is grown under shade. An exception is a ring of widely-spaced bushes surrounding the green manure show plots. This coffee is a hybrid of unknown composition, though it is inferred from records (and the characteristics of the bushes bear this out)

that it is a hybrid of canephora. These bushes are 27 years old; they are of considerable size, but look thin, straggly, and unhealthy, and show much more leaf disease than shaded coffee. Nevertheless, they have consistently borne larger crops than any other of the robusta types on the Station. The wide spacing has doubtless contributed to the yield and renders the evidence less reliable, but the general result is in accordance with the opinion of writers in other countries.

If the necessity for actual shade in coffee is admitted it follows that the choice of a tree and the control of such trees when planted will depend more upon the necessity of providing the right degree of shade than upon such consideration as the provision of a heavy quantity of loppings, etc. Anstead [4] postulates that a shade tree for coffee must not grow too big but should have a wide spread of branches so as to shade a large area and should retain its foliage during the hot weather. He adds that it should not be subject to pests and diseases which are liable to attack coffee. In the author's opinion *Grevillea robusta* is one of the best all-round shade trees for coffee in south India. He draws attention to the necessity for careful regulation of shade, since too dense a shade invariably reduces crop.

Haller [17] recommends that shade trees for coffee should be planted in avenues 10 to 15 feet apart and say 20 to 25 feet between the avenues, and that these avenues should run from east to west to ensure a lateral shadow being cast on the coffee from south to north. When the trees get bigger every alternate tree may be removed. From the fact that some of the finest coffee estates in India are found in Coorg and a mixture of shade trees is usually found there the author draws the conclusion that a variety of trees is preferable to the use of a single kind.

PROTECTION FROM WIND

Strong wind affects coffee adversely, as it does most plantation crops. Owing to the admitted necessity for shade this factor must assume predominance in considering the arrangement and spacing of shade trees. Shade trees, however planted, will help to break the force of the wind but the arrangement of avenues suggested by Haller and others will probably be more effective than even spacing. Special windbelts may be planted as is sometimes done in tea.

ROOT ACTION

Anstead [4] points out that a surface rooting tree is undesirable since it will compete with the root system of the coffee. The beneficial effect of a deep-root tree in opening the soil and improving drainage will apply as much to coffee as to tea.

NITROGEN ASSIMILATION

All that has been said in this connection with regard to tea will apply in the case of coffee. Possibly in the case of tea nitrogen is of more importance but it is an essential food element to all crops, and, provided a leguminous tree which will give the right kind and quality of shade can be found, such a tree should be chosen in preference to one of another order.

CHECK TO SOIL EROSION

This question is important with all tropical crops. Although trees will never be planted in coffee with the principal object of checking soil erosion they will nevertheless have some beneficial effect.

Anstead [4] points out that since coffee is a surface feeder the question of preventing the denudation of surface soil is even more important than with deeper-rooted crops.

A MULCH OF LEAVES

The formation and maintenance of a mulch of leaves on the surface of the soil is generally considered to be of special importance in coffee cultivation. Anstead [4] says that the merits of a shade tree should be largely judged by the mulch it produces and points out that a mulch helps to preserve the soil in that loose and open condition so necessary to the growth of crops. He gives an instance from a Mysore estate where it was found that the actual weight of leaves deposited by the coffee itself and the shade trees was over four tons per acre. Analysis showed that this quantity of mulch contained 109 lb. of nitrogen, 36 lb. of phosphoric acid, and 118 lb. of potash. All this material was placed where the feeding roots of coffee could most easily get at it. He considers that a mulch saves the necessity of digging the soil and keeps it in a better mechanical condition than the usual amount of hoeing would do.

In this connection the figures of a small one-plot experiment with robusta coffee at Peradeniya may be quoted:

Pounds fresh berries per bush

Year		Cattle manure forked in annually	Heavy mulch of dadap leaves from outside as well as leaf-fall from shade trees. No cultivation	Plain forking once annually
1921-22	...	1·78	1·94	1·10
1922-23		No yield	Bushes collar pruned	
1923-24	...	·16	·13	·17
1924-25	...	1·52	1·86	2·23
1925-26	...	2·66	3·08	3·85
1926-27	...	9·25	7·51	7·88
1927-28	...	4·93	4·72	6·22
1928-29	...	5·33	7·32	6·27
Total	...	25·63	26·56	27·72

The results of this small experiment however do not appear to uphold the superiority of mulching over cultivation.

THE CONTROL OF PESTS AND DISEASES

One of the greatest drawbacks to the cultivation of coffee without shade was found in south India to the rapid increase of the coffee borer. It was found that trees which are deciduous during the dry weather were no protection against the borer as it is during this period that the eggs are hatched. As far as is known the borer is not very prevalent in coffee in Ceylon but it exists, and the protection against it apparently afforded by shade trees forms an additional argument in their favour.

OTHER ADVANTAGES

Other advantages of planting trees in coffee are the check to weed growth, the retention of a certain amount of plant food in young clearings, and the maintenance or increase of the humus content in the soil. The latter question is always important in the tropics, but, if the widely held opinion that the maintenance of a mulch upon the surface is preferable to cultivation is correct, the digging or forking in of loppings is automatically prohibited. It cannot be regarded as certain that this always is the correct policy for Ceylon, but there is unfortunately little proof one way or the other.

THE CHOICE OF A TREE

Some of the points to be considered in choosing a shade tree for coffee have already been touched upon. They may be summarised as follows:

1. The tree should not grow too big but should have a large spread so that a small number of trees per acre will suffice.
2. It should be deep rooted so as not to compete with the surface rooting coffee.
3. It should not be liable to pests and diseases which may attack coffee.
4. It should afford a light shade so that constant lopping, accompanied by the sudden removal of all or part of the shade, is not necessary.

Of trees grown among coffee at Peradeniya, *Leucaena glauca* is considered most suitable; its spread is not very large but it has all the other qualities described as desirable. *Gliricidia* and dadaps have both been grown, but if left unlopped for long their shade becomes too dense and its sudden removal is likely to be attended with adverse results. *Leucaena glauca* does not do well above about 3,500 feet so that at higher elevations another tree must be sought. Some of the species of *Aibizzia* might be employed, but, though the type of shade they afford is generally unsuitable, the large size to which they attain is a drawback. *Albizzia stipulata* might possibly be the best as it does not grow so large. *Derris microphylla* is highly spoken of as a shade tree for coffee in Java and is well worthy of trial in the mid and low-country.

Anstead [4] considers that in south India *Grevillea robusta* is probably the best all-round tree for coffee and there is a good deal to be said in its favour for Ceyon. Various species of *Ficus* were formerly largely used in south India but apparently their popularity is declining and a leguminous plant is now generally preferred. The surface rooting propensity of *Ficus* trees is probably their greatest drawback. Where coffee is being planted on jungle land there is something to be said in favour of leaving a proportion of the forest as shade. If this is done the ground is never fully exposed to the sun and loss of organic matter is thus avoided. The forest trees can eventually be gradually eliminated when selected shade trees have been established though the process is bound to be accompanied by damage to the coffee.

NOTES ON INDIVIDUAL TREES

Information as to the use of shade trees in coffee in Ceylon is very meagre and the following notes are in consequence very brief.

Albizzia fastigiata.—No record of the use of this tree in coffee has been seen, but its exceptionally fine spread suggests it as a possible one.

Albizzia moluccana.—The same advantages may be ascribed to this tree as to *A. fastigiata.* Its large size is a drawback.

Albizzia odoratissima. Mara, Huriya (Sinh.)—Haller [17] states that this tree is used in south India. Its light shade renders it suitable for a northern aspect.

Albizzia stipulata. Sau.—This tree affords a light shade and appears suitable.

Artocarpus integrifolia. Jak. Kos (Sinh.), Pila (Tam.).—Although not leguminous this tree is considerably used in south India. Being deep rooted it does not compete with the coffee for plant food. The shade afforded, however, is not very suitable.

Dalbergia assamica.—This appears a possible shade tree for coffee at low and medium elevations.

Dalbergia latifolia. Eravadi (Tam.).—Anstead [4] records that this large tree is commonly used in south India.

Derris microphylla.—This tree is stated to be a favourite in Java. It throws a suitable light shade and appears well worthy of trial at lower elevations.

Derris robusta.—This tree has not quite the spread which is desirable, but in other respects seems suitable.

Erythrina lithosperma. Dadap. Eramudu (Sinh.), Murunka (Tam).—The dadap has been used as a shade tree for robusta coffee at Peradeniya, and elsewhere in Ceylon. It is fairly suitable but if left long unlopped its shade becomes too dense. It is used in the Dutch East Indies, but other trees, such as *Leucaena glauca* and *Derris microphylla* are now preferred.

Ficus sp.—Anstead [4] states that *F. glomerata*, *F. infectoria*, *F. isiela* and *F. mysorensis* are all used as shade for coffee in south India. The disadvantages of *Ficus* trees have already been mentioned and it is believed that they are not now so commonly planted. They supply a heavy mulch of leaves, however, and it is stated that coffee thrives well under them.

Gliricidia maculata.—This tree is used for coffee shade at Peradeniya but once it has been lopped it throws a very dense shade and the position alternates between too much and too little shade. This drawback can be mitigated by lopping only part of the branches, but there is no doubt that there are other trees more suitable.

Gliricidia maculata in coffee.

Grevillea robusta. Silver oak. Savuku maram (Tam).—As already stated Anstead [4] considers this tree to be perhaps the best all-round tree for coffee in south India. For shade it cannot be considered ideal, but the heavy mulch of leaves produced is a point in its favour.

Leucaena glauca.—This is certainly one of the best trees known in Ceylon for coffee. It is deep rooted, throws a light shade, and needs but little attention. It seeds prolifically and if the seedlings are allowed to get a hold they are hard to eradicate. Careful weeding is therefore essential. The tree has been found very satisfactory at Peradeniya.

BUSH PLANTS

Practically no information is available as to the use of bush plants in coffee in Ceylon, and but little from other countries.

Anstead [2] says that in south India coffee is planted under shade and so closely that the growth of green manures is usually prevented. He adds, however, that in young clearings green manures have proved a valuable aid to the growth of coffee. The author quotes an instance of the use of green manures on a Mysore estate where a field of old coffee was collar pruned and the land round the stumps forked. In the following year *Cassia occidentalis* was sown. When it had grown vigorously and had completely smothered the coffee it was cut down and forked in. The coffee put out new wood rapidly and two years after it had been cut down to within six inches of the ground gave a yield of 4 cwt. per acre.

In Ceylon also coffee would normally be planted so close that when the bushes are fully grown little space remains for the planting of leguminous bush plants.

In young clearings the use of bush plants would generally be attended by the same advantage as have been described for tea. A special function for bush plants in clearing is the provision of temporary shade for the young coffee plants. Shade is particularly necessary for young coffee plants and when these are first planted out the shade trees will seldom have reached the age at which they are fully functioning. A ring of tall quick-growing bush plants, such as *Crotalaria anagyroides*, *Crotalaria usaramoensis* or *Cajanus cajan*, sown round the holes a season before the coffee is planted, will supply the deficiency.

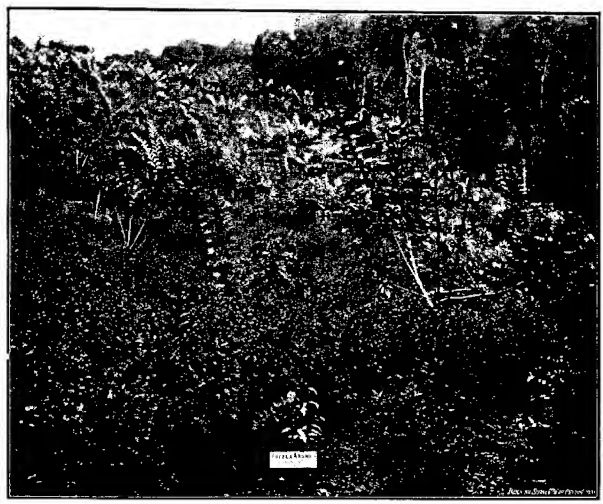
The number of bush plants on which information as to special use in coffee is available is so small that it is thought hardly worth while to compile a list. Practically any of the plants which have been favourably spoken of for tea could be used with

advantage in young coffee clearings. Anstead [4] mentions that various species of *Tephrosia*, *Indigofera*, *Cassia*, and *Desmodium* are common in Mysore and have been used with advantage. The same writer in another publication [2] mentions especially *Cassia hirsuta*, *Cassia mimosoides*, *Indigofera tinctoria* and *Crotalaria heptaphylla* as being commonly used in the green manuring of young coffee in south India. A writer from Java enumerates the following plants as having been found especially suitable for use on coffee estates in that Island: *Tephrosia candida*, *Tephrosia vogelii*, *Crotalaria striata*, *Crotalaria juncea*, *Crotalaria quinquefolia*. *Tephrosia noctiflora* is being grown among Arabian coffee on the Experiment Station, Peradeniya. This plant from its low habit is less likely than the larger kinds to interefere with the coffee bushes.

GROUND COVER PLANTS

Even less information is available as to the use of ground cover plants. As coffee is a surface feeder it might be considered undesirable to plant a surface rooting cover that would compete with the coffee. On the other hand the fact that coffee is a surface feeder renders the prevention of soil erosion all the more urgent. In young clearings the use of a ground cover plant would appear just as desirable as in tea, provided that care is taken that the cover is kept clear of the young coffee plants. As in the case of tea a plant that will not climb up and smother the bushes should be chosen for preference, and *Indigofera endecaphylla* would appear eminently suitable. This creeper has been planted round the edges of roads and drains in six acres of coffee at the Experiment Station, Peradeniya. The creeper has been allowed to spread at will through the coffee and the bushes surrounded by this creeper appear at least as healthy as those in clean-weeded land. Where coffee, especially the robusta types, is planted close and has developed well, the shade afforded (in addition to that of trees) will be so dense that the establishment of *Indigofera* will be hardly practicable. On steep slopes, however, where the growth is poor the planting of a suitable ground cover plant can be recommended.

Another writer from Java mentions that the creepers *Centrosema plumieri*, *Pueraria phaseoloides*, *Phaseolus mungo*, and *Vigna sinensis* have been found especially suitable for use on coffee estates. It is not stated whether these plants were used in clearings or in old coffee. These creepers are all strong climbers and if planted near the coffee would need careful controlling.



Indigofera arrecta in young coffee with *Gliricidia maculata* as shade

CACAO

Shade is usually the prime consideration in interplanting trees and bush plants in cacao. The heading shade will be taken to include temporary as well as permanent shade, and, as bush plants are considerably used for the former purpose, these two types of plants will be considered together.

TREES AND BUSH PLANTS

SHADE

Whatever doubts there may be about the necessity for permanent shade in cacao, there appears to be a general agreement that young cacao must have shade, and this is usually provided for two to three years. If the permanent shade trees are planted at the same time as the temporary shade they will probably afford the necessary shade by the end of that period.

Temporary shade is provided by planting rows of bush plants or small trees alongside the rows of cacao. In many countries plants of economic value are used for this purpose i.e., a system of catch-cropping is adopted which achieves the double object of providing some monetary return before the cacao comes into bearing and of shading the young plants. A description of this form of cultivation may be outside the scope of this treatise; yet it is impossible to separate shading and green manuring, and no account of shading cacao would be complete without a description of these practices.

The plants used for temporary shade for young cacao are many and various. Wright [34] mentions that in Java *Erythrina* and *Manihot* (Cassava) are recommended.

Hart [18], writing of the West Indies, says that the following plants are commonly used: *Zea mais* (Indian Corn), *Cajanus cajan* (Pigeon pea), *Ricinus communis* (the castor oil plant), *Manihot utilitissima* (Cassava), *Musa sapientum* (banana), and various kinds of tannias and eddocs (edible yams). He says that the distance of planting is immaterial, provided the young cacao is adequately shaded.

Hall [16], writing of Java, endorses the view that temporary shade should always be provided and recommends the planting of bananas 10 to 15 feet apart. He says that too close planting of temporary shade will produce tall spindly cacao plants. The author then describes a system of planting *Leucaena glauca* so that some plants are kept for permanent shade and others used for temporary shade and later eradicated. It is not thought, however, that *Leucaena glauca* is likely to prove suitable as permanent shade for cacao in Ceylon, and for temporary shade

the difficulty of eradicating the trees would be a drawback. The same author enumerates a large number of other plants used in Java as temporary shade, including species of *Xanthosoma* and *Colocasia* (edible yams), *Ricinus communis*, *Manihot utilitissima*, *Indigofera* sp., *Cajanus cajan*, and *Clitoria cajanifolia*. Judging by its habit in Ceylon, the last-named is not considered suitable.

In Surinam the banana is commonly used as a temporary shade.

In Madagascar also the banana is used, *Albizzia Lebbek* being usually planted at the same time for permanent shade.

Wright [34] states that in Samoa *Papaya carica*, the papaw, is used.

Hall [16] discusses the practice that is sometimes adopted of leaving a proportion of the forest trees for shade when land is being cleared for cacao. He does not regard this practice with favour as the shade left by large forest trees is not of the kind needed for young cacao plants.

Ceylon estates have given no information as to temporary shade in the replies to the circular sent out. There is little doubt, however, that cacao in Ceylon requires shade from the start. The area of cacao on the Experiment Station, Peradeniya, known as the "B" cacao, was originally divided into three plots—no shade, high shade, and low shade. It is recorded that there was little difference in the growth of cacao in the high shade and low shade plots, but that in the plot without shade, growth was so poor and such a large number of casualities occurred that the cacao was abandoned and rubber was planted instead. It is believed that in this instance only permanent shade trees (*Erythrina lithosperma*) were planted, and that no special provision was made for temporary shade.

The advantages of a leguminous plant over a non-leguminous plant have been already fully discussed. Nevertheless, the advantages of utilising a plant which will provide some monetary return before the cacao comes into bearing are obvious, and the practice probably deserves more attention than it receives in Ceylon. Plantains can still be grown with profit and possibly form the most suitable locally-grown economic crop for temporary shade for cacao. Of leguminous bush plants, *Tephrosia candida*, *Tephrosia vogelii*, *Cajanus cajan*, and *Desmodium gyroides* all appear suitable. The *Crotalarias* are usually too short-lived to be effective.

The provision of permanent shade for cacao is considered to be necessary in most cacao-growing countries, though there are exceptions.

Wright [34] points out that the cacao tree is not a robust plant and in its natural state is usually shaded by the larger forest trees. He states that shade is provided in most of the cacao-growing countries in Africa, *Erythrina* sp. being largely used. In Madagascar the opinion is held that shade can be reduced as the cacao grows older. He states that in Nicaragua and other Central American countries shade is extensively used, the trees commonly planted being *Gliricidia maculata*, *Jatropha* sp., *Caesalpinia exostemma*, and *Erythrina* sp.

Hart [18] says that a great diversity of opinion exists as to the necessity of shade but that he himself has been converted to the view that shade is necessary in moderation. He states that in Trinidad *Erythrina umbrosa* and *Erythrina velutina* are the two trees most commonly used. He points out that an estate in the plains which gets sun all day requires denser shade than one which is shaded part of the day by the hills and further states that Baron Eggers, a Danish botanist, has reported that in the forests of Equador, where the distribution of cacao depends mostly on the scattering of the seed by monkeys, trees found in the open are always stunted. Hall [16] considers shade is desirable, though probably not essential. He mentions a considerable number of shade trees used in Java. The author also discusses the possibility of growing trees of economic value as permanent shade trees for cacao. This possibility has been investigated in many cacao-growing countries, but it is usually found that trees of economic value do not afford the most suitable shade.

Several of the rubber-producing trees have been tried, but as all these trees, except *Hevea brasiliensis*, have lost their commercial importance, and as the latter tree is not particularly suitable as a shade tree, the question appears to have lost interest.

Kapok is said to have been successfully interplanted among cacao in Java but the shade afforded by this tree would not usually be considered sufficient, and the harvesting of the Kapok crop would be difficult. A further point against the sole employment of trees of economic value as shade for cacao is that it would seldom be possible to lop them, and the regulation of shade would thus be difficult.

It is now necessary to consider the views of those who consider permanent shade to be unnecessary. The Island of Grenada forms the best known example of the successful cultivation of cacao without shade. Hart [18] points out that in Grenada the cacao districts are very hilly and the trees are

naturally shaded by the hills for some hours of the day. Hall[16] remarks that in Grenada cacao is planted very close (9 feet or at the most 12 feet apart), tillage is invariably carried out, and large quantities of cattle or sheep manure are applied. He argues from this that actual shade for cacao is probably not necessary and that the other advantages of planting leguminous trees, e.g., shading of the ground, root action, nitrogen assimilation, increase of organic matter etc. are more important, and that in Grenada these benefits are obtained in other ways, e.g., ground shade by close planting, loosening of the soil by tillage, and nitrogen and organic matter by bulk manuring.

In the West Indies in general there is a diversity of opinion as to the necessity for shading cacao. Shade is generally planted but, in addition to Grenada, cacao is successfully grown without shade in parts of Jamaica and Dominica. In Brazil and San Domingo cacao is also often grown without shade. Hall [16] states that cacao grown without shade comes into bearing earlier, gives heavier crops, and is less liable to certain diseases; its life, however, is shorter.

There seems a good deal to be said for the argument that actual shade is not required and that the benefits accruing from the planting of shade trees can be obtained in other ways. This, however, does not constitute an argument against the planting of trees in cacao, since it would appear that the benefits referred to can be more easily and more cheaply obtained by the planting of leguminous trees than by any other means. Wright [36] says that in Ceylon the benefits of shade have been convincing, and in view of the evidence quoted it may be taken that the interplanting of leguminous trees among cacao is a practice to be strongly recommended.

The regulation of such shade is, however, a matter of first importance. Hart [18] emphasises the fact that too little or too much shade are both bad. He points out that densely shaded cacao is more liable to fungoid diseases, but that unshaded cacao is more liable to attack by insect pests. A Ceylon superintendent also states that shade reduces *Helopeltis*.

The early records of the Experiment Station, Peradeniya, show clearly the evil effects of overshadowing cacao and demonstrate that this factor has more influence on crop than any other. Excessive shade was found to reduce crop in years which were in general good cacao years, while when the lopping and proper control of shade trees were undertaken, improved yields at once resulted.

Wright [34] says that as a general principle shade trees should be regularly lopped during the dull weather and allowed to develop and retain their full foliage during the hot dry weather during which period the leaves which have accumulated on the ground will serve as a mulch and check the evaporation of moisture. This appears to be sound general advice; the amount and nature of the lopping required will vary with the type of tree planted.

SHELTER FROM WIND

Cacao is very sensitive to strong wind and while ordinary shade trees will always afford some protection, the planting of additional windbelts may in certain circumstances be necessary.

In Samoa it is recommended that strips of the original jungle should be left, or alternatively lines of rubber trees planted, to break the force of the wind. In Guam (one of the Marianne Islands in the Philippine group) the question of wind appears to have received even more attention than that of shade. Rows of bananas are planted for wind protection, or belts of forest trees left.

It is not possible to give general advice on a matter of this kind and the circumstances of each case must be considered. Attention is invited to the portion of this section dealing with wind protection for tea.

It is to be noted that some of the trees used for shading cacao, e.g., *Erythrina umbrosa*, are themselves very liable to be blown down by strong winds, causing great damage to cacao. The use of such trees in windy situations is therefore to be avoided.

ROOT ACTION

The benefits of the root action of trees in opening up the soil and improving drainage have been several times alluded to. Generally speaking, a deep-rooted tree will be more effective in this respect.

NITROGEN ASSIMILATION

The reasons in favour of the preference for a leguminous tree in tea and coffee hold equally good in the case of cacao.

CHECK TO SOIL EROSION

The question of soil erosion in old cacao is not usually so acute as in other crops owing to the heavy cover afforded by the cacao trees themselves and the considerable mulch of leaves found under them. Shade trees will help, but the prevention of erosion is not one of the main reasons for planting them.

A MULCH OF LEAVES

There is considerable evidence that a heavy surface mulch is very beneficient to cacao. Early experiments carried out in Dominica in 1906 demonstrated forcibly the value of a heavy mulch of grass and leaves to cacao. This treatment in fact resulted in a greater, more lasting, and more profitable increase in yield than any of the manurial applications included in the experiment. In 1913-14, with a view to deciding the quantity of mulch necessary, in the place of 4 and 5 tons previously applied, a plot was started which received only $2\frac{1}{2}$ tons per acre. In three years the yield of this plot was nearly doubled.

In view of this striking evidence any addition to the mulch of leaves from the cacao afforded by the leaf-fall and loppings from shade trees must be regarded as a major asset.

INCREASE OF ORGANIC MATTER

Hardly any mention is made by writers from other countries or by Ceylon superintendents, of burying the loppings of shade trees. It may well be that in view of the benefits of mulching it is preferable to leave loppings on the surface rather than to bury or fork them in. This is believed to be the usual procedure on Ceylon estates. Only one estate reports the burying of loppings.

THE CHOICE OF A TREE

Sufficient has already been said about the choice of a small tree or bush plants for purposes of temporary shade.

The choice of a permanent shade tree for cacao is somewhat more difficult owing to the large number of trees that have been used or recommended in different countries.

Wright [34] gives a long list of possible shade trees for cacao in Ceylon, but makes no positive recommendation and merely states that the trees most commonly used are *Albizzia* sp., *Erythrina* sp., *Hevea brasiliensis*, *Castilloa elastica*, and *Manihot glaziovii*. The last two are rubber-producing trees which were still of possible economic importance in Wright's time. They are not now of commercial importance in Ceylon and neither of them nor *Hevea brasiliensis* can be considered a really suitable shade tree for cacao. In the replies to circulars sent out to estates only *Albizzia*, *Erythrina*, Jak, and *Gliricidia maculata* are mentioned. Coconuts are often interplanted, but generally as an economic crop and the coconut palm is not suitable as sole shade for cacao. In the small gardens in which cacao is found in the Kandy district dense mixed planting of cacao, jak, coconuts, arecanuts, and other trees and plants is usually

found. The cacao is almost always overshadowed and if records were available it would probably be found that crops are very poor. Certainly canker and other diseases are very prevalent.

If it is admitted that there is no tree of economic value that is entirely suitable as the sole permanent shade for cacao the choice should rest on a leguminous tree unless no suitable tree of this order can be found. It will be advisable first to ascertain whether any of the trees in general use are entirely suitable and if not make recommendations based on experience in other countries. Undoubtedly *Erythrina* spp. are more widely used than any other tree in Ceylon. *Erythrina lithosperma* is the only shade tree used for cacao on the Experiment Station, Peradeniya, but cannot be considered entirely satisfactory. The trees were apparently planted in 1904, though doubtless some are supplies of a later date. During the last 10 years a large number of these trees have been blown down and during 1929 and 1930, the trouble has been acute. The inference is that the trees should have been replaced earlier but even so it is impossible to remove trees of this size without considerable damage to cacao. The poor root system of *Erythrina* certainly constituted a serious disadvantage.

Albizzia moluccana is probably the next commonest tree. When the Government took over the Experiment Station in 1902 the cacao was densely shaded by *Albizzia* which, in the words of the first manager, had grown into "a veritable forest". The removal of the trees was at once commenced and when *Erythrina* had later been planted great improvement in the cacao was reported. It would appear possible, however, that the fault lay rather in the close planting than in the nature of the tree. *Albizzia moluccana* gives a large spread and a light filtered shade and would appear, if planted at suitable intervals, to be a useful tree for the purpose. The difficulty of removing the trees when they reached the limit of their useful life is even more acute than with *Erythrina* and probably constitutes their greatest drawback. Moreover, the replanting of these trees in old cacao would be very difficult.

Artocarpus integrifolia, the Jak, is not leguminous and does not throw a suitable shade.

Gliricidia maculata is the only other tree mentioned as being used for cacao shade in Ceylon. The tree, however, does not usually grow to a sufficient height, nor is the type of shade very suitable.

None of the trees usually used in Ceylon can therefore be considered ideal and it may be advisable to study recommendations made in other countries.

Hart [18] considers that although the *Erythrinas* are in almost universal use in the West Indies *Pithecolobium saman*, the rain tree, is really a much more suitable tree. In addition to affording suitable shade its timber is valuable, while the wood of the *Erythrinas* is practically valueless. *Pithecolobium saman* flourishes in Ceylon at elevations at which cacao is grown and would appear to be quite suitable.

Hall [16] states that *Derris microphylla* has come into considerable use in Java. It is known to do well in the low-country in Ceylon and might do well for cacao. Hall also states that *Caesalpinia dasyrrachis* is being used to some extent in Java in place of *Erythrina* as the tree is less prone to disease.

Macmillan [27] and Wright [34] mention the possibility of the use of *Adenanthera pavonina*, the bead tree. This certainly grows well at Peradeniya, but its short life is a disadvantage. *Derris robusta* also suggests itself as a possibility.

There would appear then to be no need to adhere to the *Erythrinas*, since there are promising alternatives.

REPLACEMENT AND ERADICATION

Most superintendents who have given information as to shade trees in cacao agree as to the necessity of periodical replacement of these. The experience of the Experiment Station with *Erythrina lithosperma* appears to confirm this. Unfortunately, though easy to recommend, such a policy is very difficult to carry out. A shade tree for cacao must be a large tree and the removal of such trees not only absorbs a great deal of labour but of necessity results in much damage to the cacao. The planting of fresh shade is also a difficult matter. It is possible to establish large cuttings of *Erythrina* in old cacao but not easy. It is thought that the establishment of seedlings in similar circumstances would be even more difficult.

Several estates, however, report that the replacement and removal of old trees is periodically carried out but the difficulties involved make it desirable that a tree with as long a life as possible should be chosen.

NOTES ON INDIVIDUAL TREES AND BUSH PLANTS

Of the following trees no information is to hand of their actual use in cacao either in Ceylon or elsewhere: *Acacia pycnantha*, *Albizzia odoratissima*, *Artocarpus nobilis*, *Azadirachta indica* (Margosa), *Cassia siamea*, *Casiarina equisitifolia*, *Cedrela serrata*, *Cedrela toona*, *Erythrina ovalifolia*, *Eucalyptus leucoxylon*, *Eucalyptus marginata*, *Euginia jambos*, *Filicium decipiens*,

Melia dubia (Lunumidella), *Mesua ferrea* (iron tree), *Myristica laurifolia*, *Pterocarpus indicus*, *Pterocarpus Marsupium*, *Tamarindus indica* (Tamarind), and *Veteria acciminata*.

Adenanthera microsperma.—Hall [16] mentions that this tree is used for shade in Java. It is a rapid grower but its wood is very brittle and its life is short.

Adenanthera pavonina. Bead tree. Anaikuntumani (Tam.). Hall [16] gives the same description of this tree as of *A. microsperma*. Wright [34] suggests it as a shade tree for Ceylon, but its short life would be a drawback.

Albizzia fastigiata.—This tree should be as suitable as *A. moluccana* which it much resembles.

Albizzia moluccana.—This tree is in use in Ceylon. It attains a large size and throws a light and suitable shade. Lopping is not advised, as, if planted at suitable distances, the shade is not too heavy; moreover, the lopping of large trees is practically impossible.

Albizzia stipulata.—Wright [34] mentions this as a possible shade tree for Ceylon, but the fact that the tree is leafless for a period up to three weeks at the beginning of each year is a disadvantage. In Java it is recommended in preference to *A. moluccana* or *A. Lebbek* on account of the greater value of its timber. It is used also in Samoa.

Artocarpus integrifolia. Jak. Kos (Sinh.), Pila (Tam.).—Several estates in the Kandy district use this tree in conjunction with *Erythrina umbrosa*. One estate reports that it takes up more moisture than *Erythrina* and its roots interfere with the cacao. Neither its shape nor the kind of shade afforded render the jak really suitable.

Caesalpinia dasyrrachis.—Hall [16] reports that this tree has come into considerable favour in Java and has to some extent superseded *Erythrina*.

Caesalpinia exostemma.—This tree is commonly used in Nicaragua.

Cajanus cajan. Dhall, Pigeon pea. Rata thora (Sinh.), Invarai (Tam.).—Hart [18] says that this shrub is used as temporary shade for cacao in the West Indies. Hall [16] observes that it is put to the same use in Java, but is not very popular, possibly because its economic value is less than that of the banana or cassava. The same argument would hold good in Ceylon and in the Kandy district the seed pods are nearly always badly attacked by insects.

Castilloa elastica. Catilloa rubber.—Wright [34] mentions that this large tree has been successfully grown in conjunction with cacao in Ceylon, Java, British Honduras, and Tobago. A drawback to the tree is that it is usually leafless during a part of the hot dry weather. The tree is now of no economic value in Ceylon and cannot be recommended.

Cedrela odorata.—Hall [16] quotes this as a fairly quick-growing shade tree for cacao.

Colocasia sp. Tannias, Eddoes, Cocoes.—Various edible yams have been used for temporary shade for cacao in the West Indies. Similar kinds are largely grown in Ceylon and some could be used for the same purpose.

Derris microphylla.—Hall [18] states that owing to the numerous pests and diseases attacking *Erythrina* in Java, *Derris microphylla* has come into considerable use. It grows well in the low-country in Ceylon, but the maximum elevation at which it will thrive is not certain. If suitable for the cacao districts it should prove a useful shade tree.

Derris robusta.—The growth and habit of this tree at Peradeniya, suggest that it could well be employed as a permanent shade tree.

Eriodendron anfractuosum. Kapok, Silk cotton tree. Pulun imbul (Sinh.), Illanku (Tam.).—Hall [16] states that it is often interplanted among cacao in Java, where in addition to affording shade, it serves an economic purpose. Satisfactory crops of kapok and cacao are stated to have been obtained. It is not thought, however, that the tree by itself affords sufficient shade and the harvesting of kapok among cacao cannot be a very easy matter.

Erythrina indica. Eramudu (Sinh.), Murunka (Tam.).—This is a thorny variety which is used in St. Lucia, and elsewhere. It is useless for three weeks to a month during the hot weather and this characteristic as well as the fact that it possesses thorns are sufficient reasons for not recommending it.

Erythrina lithosperma. Dadap. Eramudu (Sinh.), Murunka (Tam.).—This is by far the most widely-used shade tree for cacao in Ceylon. In order to regulate the shade it is usual to lop the trees once a year. One estate reports that the trees are lopped once in four years only. As it is undesirable that all the shade should be removed at once the system on the Experiment Station, is to lop only the central branches, leaving the side branches untouched. The trees have a poor root

Erythrina lithosperma as shade for cacao

system and when they get old are easily blown down with resultant damage to cacao. Replacement in old cacao is possibe but not easy. A large cacao estate near Kandy reports that for this purpose 8 to 10-foot cuttings are planted in holes. When they grow up they are kept clear of side branches, or such as interfere with cacao, and are pollarded at about 25 feet. The original spacing employed on that estate is about 20 to 24 feet and thinning-out is done later when the shade gets too dense. The removal of fallen trees has usually been beyond the labour resources of the Experiment Station, but it is to be noted that no case of root disease has occurred which could be traced to decaying dadap logs.

Erythrina umbrosa. Dadap, ananea, mortel, immortelle.—This is the almost universal shade tree for cacao in the hills in the West Indies where the usual spacing is 40 to 45 feet each way. It is also used in Java.

Erythrina velutina. Bocare, mortel, immortelle.—This tree is extensively used in Trinidad and forms the usual cacao shade for the plains in the West Indies. It is usually planted 35 to 40 feet apart. It is also used in Java but is not common in Ceylon

Gliricidia maculata.—There appears to be a confusion between this tree and *Gliricidia sepium.* One or the other is extensively used as a shade tree in Nicaragua where it is usually planted 30 to 35 feet apart in alternate lines of cacao.

One estate reports its use in Ceylon but it is not thought that the tree usually grows to a sufficient height nor does its habit or the shade it affords suggest the ideal type of tree for shading Ceylon cacao.

Inga laurina.—Macmillan [27] states that this tree is used in the West Indies as shade for cacao.

Hevea brasiliensis. Para rubber.—This has been interplanted among cacao in Ceylon and elsewhere, but more on account of its economic value than its suitability as a shade tree. Its extensive root system and the fact that it is leafless for part of the hot weather renders it unsuitable.

Leucaena glauca. Lamtoro.—Hall [16] mentions the use of this tree in Java, both for temporary and permanent shade for cacao. It does not appear to be particularly suitable for either purpose.

Mangifera indica. Mango. Amba (Sinh), Mankai (Tam). —Wright [34] states that this tree is in use in Ceylon as a shade tree for cacao. The shade it affords is probably too dense to make it suitable.

Manihot utilitissima. Cassava, Tapioca. Manioka (Sinh. and Tam.).—This well-known food plant is used as temporary shade for cacao in the West Indies, Java, and elsewhere. It is easily grown and is suitable as far as habit and shade are concerned, but it has the reputation of exhausting the soil and on this account cannot be strongly recommended.

Musa paradisiaca (*Musa sapientum*). Plantain, banana. Kehel (Sinh.), Vallai (Tam.).—A distinction is drawn between plantains and bananas in many countries, but in Ceylon all varieties are known as plantains. The plant is largely grown in many cacao-growing countries as temporary shade for cacao and on account of its economic value is a useful plant for the purpose.

Papaya carica. Papaw.—Wright [34] mentions the use of this plant as a temporary shade for cacao in Samoa. It has an economic value, but the shade afforded would appear rather inadequate.

Pithecolobium saman. Rain tree.—This tree is also frequently known as *Inga saman*. Hart [18] considers the tree more suitable for cacao than the *Erythrinas* in common use in the West Indies. It thrives in Ceylon in the cacao districts and would appear to have a good deal to recommend it. It is hardy, long-lived, and stands lopping well. Wide spacing, say 50 to 60 feet, would be necessary. The timber is of some value.

Peltophorum ferrugineum. Iya vakai (Tam.).—Hall [16] mentions the tree as a fairly quick-growing shade tree for cacao in Java. Wright [34] mentions it as a possibility in Ceylon, but it does not appear to have been tried.

Ricinus communis. Castor oil. Erandu (Sinh.), Chittamanakku or Amanakkam (Tam.).—Hart [18] mentions the possibility of the use of this small tree for temporary shade for young cacao, and Hall [16] states that it is occasionally, but rarely used for this purpose in Java. It is of some economic value and its habit is suitable for the purpose.

Sterculia foetida. Telambu (Sinh.), Pinari (Tam.).—Wright [34] states that this tree is sometimes used as shade for cacao in Ceylon.

Swietenia macrophylla. Large leaved mahogany.—Wright[34] and Hall [16] mention this as a possible shade tree for cacao. It grows well at Peradeniya, but has hardly the spreading habit and light foliage which is desirable.

Tithonia diversifolia. Wild sunflower. Nattasuriya (Sinh.), Suriya-kandu (Tam.).—The value of mulching for cacao has

already been mentioned and this plant, which grows wild in great profusion throughout the cacao districts of Ceylon, forms probably the best source of green material to be cut and brought in from outside.

Zea mais. Indian corn, maize.—Hart [18] says that this plant is used for temporary shade in the West Indies.

GROUND COVER PLANTS

Hardly any mention, either in Ceylon or elsewhere, is found of the use of ground cover plants in cacao. In old cacao the dense ground shade cast by the cacao and shade trees, and the heavy mulch of leaves usually found, would probably preclude the use of ground cover plants.

In young clearings on steep land the arguments which have been given in favour of the use of such a plant in tea and coffee would appear to hold good for cacao. Care would have to be taken that neither the young cacao plants nor the temporary shade plants were smothered, and probably a non-climber, such as *Indigofera endecaphylla*, would be preferable.

CHANGES IN BOTANIC NAMES

Throughout this section the botanic names by which the plants mentioned have come to be most generally known, or by which they are alluded to by the authorities quoted, have been used. In many cases these are not now held to be the correct names and the following list gives the names used, together with the correct botanic names:

Names used	Correct names
Albizzia moluccana	*Albizzia falcata*
Albizzia stipulata	*Albizzia chinensis*
Caesalpinia dasyrrachis	*Artocarpus integra*
Artocarpus integrifolia	*Peltophorum dasyrachis*
Cedrela serrata	*Toona sinensis*
Cedrela toona	*Toona sinensis*
Clitoria cajanifolia	*Clitoria laurifolia*
Eriodendron anfractuosum	*Ceiba pentandra*
Erythrina indica	*Erythrina variegata*
Erythrina ovalifolia	*Erythrina fusca*
Ficus infectoria	*Ficus lucescens*
Ficus mysorensis	*Ficus cotoneaefolia*
Myristica laurifolia	*Myristica dactyloides*
Malia dubia	*Malia composita*
Peltophorum ferrugineum	*Peltophorum inerme*
Pithocolobium saman	*Enterolobium saman*
Sesbania aegyptica	*Sesbania sesban*

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SECTION III

THE GREEN MANURING OF RUBBER

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I HISTORICAL INTRODUCTION

IN the early days of rubber planting the importance of the conservation of the surface layers of soil was not fully recognised. For the prevention of soil erosion on steep land entire reliance was placed on earth works, such as drains, stone-terraces, and silt-pits, the utilization of which is now regarded as only a second line of defence. On European managed plantations clean weeding was an almost universal practice, and in no country were planters more ruled by this custom than in Ceylon. To keep the estate free from weeds was the test as to the fitness of a planter to keep his billet.

That the damage done to bare soils exposed to a tropical sun and rain was realised by some to be of great consequence is, however, shown by the following extracts from "*Hevea brasiliensis* or Para Rubber" by Herbert Wright, 1912 [1]. "Planters, even in Ceylon, are convinced that it is impossible to exaggerate the soil loss that must take place when young clearings are, year by year, exposed to tropical heat and rain, and scraped by weeding contractors". "Clean weeding in the tropics, though appalling in its effects on the soil and costly to the enthusiasts accustomed only to agriculture in temperate zones, seems, nevertheless, to be the most desirable system from the commercial point of view". The latter sentence summarises the view-point of advanced planters at that time. Quoting again from Herbert Wright's book, clean weeding "is the only system whereby labour can be retained, costs kept near the minimum, and the *Hevea* trees made to show the most rapid growth".

From an agricultural point of view the main objection to a ground cover appears to have been the conviction that the growth of the rubber trees would be thereby greatly retarded. The impoverishment of the soil and competition for moisture by weeds was held to more than counterbalance their value as preventives of soil movement. Although it was recognised

that leguminous crops could be utilised so as to enrich rather than impoverish the soil, their establishment as green manures growing amongst the rubber was opposed mainly on account of the increased difficulty and expense of weeding. To keep weeding costs as low as possible it was essential that all weeds be eradicated and the ground kept entirely clean. A few planters practised a system of "selective weeding" whereby those weeds thought to be obnoxious, such as "*illuk*" and other grasses, were removed and the harmless species retained, but the great majority of visiting agents and planters condemned any system other than that of clean weeding from the first.

In direct contrast to these methods it is now the almost universal practice to keep a permanent ground cover under rubber of all ages, and many lakhs of rupees have been spent in the establishment and utilization of leguminous crops. To what can such a complete reversal of policy be ascribed? The retarding influence of weeds on the growth of young rubber cannot be entirely denied, and on new clearings even leguminous crops may cause a temporary check to growth. There can be no doubt, however, that on the one hand the harmful influence of weeds was greatly exaggerated, and on the other the importance of checking soil erosion underestimated. In course of time the scouring effect of tropical rains became manifested on the older estates by exposure of lateral roots, unhealthy foliage and stag-heads on hill slopes, and diminution in yields, and it became evident that unless effective measures to prevent soil erosion were adopted, the surface soil, containing most of the plant foods and humus, would soon be entirely washed into the sea.

Planters are justifiably conservative as regards agricultural politics, and it was perhaps natural that those of Ceylon, formerly so ardently attracted to clean weeding, should require more convincing than those of other countries. In Java and Sumatra, the beginning of the last decade saw a greatly extended use of green manures and ground covers, experiments with various species of *Leguminosae* having been carried out by the experiment stations during the previous few years. In 1920 many thousands of acres of both young and mature rubber were under a ground cover in both these countries, though on many estates this cover consisted simply of weeds and indigenous *Leguminosae*. Interest in green manures was stimulated in Malaya in about 1922. The establishment of leguminous plants on new clearings soon became a general practice. But for some years opinion was sharply divided as to the rival

merits of clean weeding and ground covers under mature rubber. Owing to the flat and almost peaty nature of much of the coast land in Malaya, the problems of soil erosion and conservation of humus were not of such acute importance as in other countries. In South India clean weeding was formerly as general a practice as in Ceylon, and the loss of top soil in conjunction with *Phytophthora* leaf-fall was largely responsible for the poor conditions and low yields of many estates in that country. Early in the last decade *Tephrosia candida* (Boga medeloa) became popular as a green dressing, and in more recent years the use of a leguminous ground cover has become almost universal.

The attention of agriculturists in Ceylon was forcibly directed to the question of soil erosion in the Department of Agriculture *Year Book* for 1924, and it was then stated to be the most serious agricultural problem with which the country was faced. In addition to the provision of adequate drains, stone-terraces, and silt-pits, the use of contour hedges and ground cover crops was advocated. In 1926 the Director of Agriculture [2] was able to report that most estate superintendents were taking the question of soil erosion in hand and that considerable progress had been made on old and young rubber estates. Although the growth of leguminous crops on new clearings quickly became an established practice, the "die-hard" advocates of clean weeding advanced various objections to their adoption on old estates. Increased cost of weeding, danger from snakes and leeches, competition with the roots of the rubber trees for food substances and moisture, and increased danger from root diseases, were amongst the objections advanced against green manures and cover crops. The majority, however, soon realised that these disadvantages were outweighed by the conservation of soil and improvement in fertility effected.

In all countries difficulty was at first experienced in establishing and retaining a permanent ground cover in heavy shade, and many species of *Leguminosae* were tried. The use of most of the ground covers at present in vogue originated in Java and Sumatra, but the quest for further suitable species is now also being conducted in other rubber-growing countries. In Ceylon the establishment of erect shrubby green manures has been almost confined to new clearings, and in no country have the possibilities of providing the maximum quantity of green material for mature rubber been fully exploited. As will be evident from the succeeding paragraphs there is at present a wide selection of green manures and cover crops available for use under various conditions.

The extension of the cultivation of green manures and cover crops on rubber estates during the past ten years has been one of the most notable developments in the rubber plantation industry. From a position in which the retention or establishment of any crop other than *Hevea* was almost universally condemned, the cultivation of green manures and cover crops has grown until it now fills one of the most important places in the agricultural routine of the estate.

II FUNCTIONS OF GREEN MANURES AND COVER CROPS

In contradistinction to the practice in Europe and America the term "green manures" refers, in the East, not only to plants grown solely for the provision of green material, but also to cover crops and even to high shade plants. There can be no hard line of distinction between green manure crops and cover crops since each fulfils in part the functions of the other. The functions of green manures, in the broadest sense, are the conservation of the surface soil and the improvement of its fertility. In more detail, the benefits derived from the cultivation of such crops on rubber estates may be briefly described as follows:

(1) The prevention of soil erosion due to the wash of tropical rain.

(2) The protection of the soil and lateral roots from the excessive heat of the sun.

(3) The addition of humus to the soil by the natural leaf-fall, and incorporation of leaves and decaying stems.

(4) The improvement of the physical condition of the soil due to root penetration.

(5) The retention of moisture in the soil as the result of improved tilth.

(6) The conservation of the fertility of the soil by taking up available plant food which might otherwise be lost. This is partly returned to the soil by leaf-fall and when loppings are buried.

(7) The fixation of additional nitrogen from the air (in the case of leguminous plants).

(8) The reduction of weeding costs, obviating the harmful scraping on bare soils.

Although it is difficult to draw a hard line of distinction between green manures and cover crops there are clearly certain types which are more effective as sources of green

material, and others whose main value is a ground cover. In general the erect shrubby species provide the greatest quantity of leaf mulch though they are obviously less effective as preventives of soil movement than ground creepers. The former are mainly soil builders and the latter soil conservators, and the two types must be used in conjunction if the maximum benefit of each is to be obtained.

III GREEN MANURES AND COVER CROPS IN NEW CLEARINGS

The principle of growing cover crops and green manures was more quickly assimilated and adopted in new clearings than under mature rubber. In the first place the necessity for protecting the newly-exposed soil from the ravages of tropical heat and rain was more immediately evident, and in the second place the establishment of covers is more easily effected and a greater choice of suitable species available. Although there still remain a few advocates of clean weeding under mature rubber, it is doubtful if the most conservative planter can deny the tremendous benefits which may be obtained by the growth and utilization of green manures and cover crops on newly-opened land.

There are various minor objections to the growth of any subsidiary crop in conjunction with young *Hevea* plants, but these can mostly be obviated by selecting the most suitable species and taking the necessary precautions. Once established the cover should be kept some distance from the young rubber plants to avoid any serious competition for water and plant food. The danger of low-growing creepers twining round the young plants and smothering them is thus also obviated. It is possible that in any event the growth of the young rubber may at first be slightly retarded, but this disadvantage is far outweighed by the subsequent benefits conferred by a fertile soil.

(1) CHOICE OF SPECIES

Cover plants may be divided into two distinct types:

(a) Low-growing types especially valuable for the prevention of soil wash.

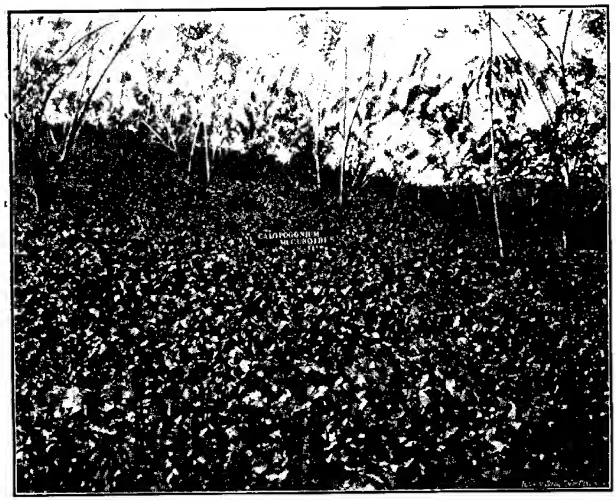
(b) Erect shrubby types more suitable for the provision of green manure.

Both these types are valuable on new clearings, and are used in conjunction with one another.

(a) *Ground Covers.*—Desirable attributes of a ground cover may be enumerated as follows:

Dolichos Hosei (Vigna oligosperma) in young rubber

Centrosema pubescens with Wind-belts of *Gliricidia maculata*



Calopogonium mucunoides in young rubber

Pueraria phaseoloides (P. javanica)

(1) A perennial plant is preferable to an annual on account of its greater permanency.

(2) Plants belonging to the family *Leguminosae* are preferable to others on account of the nitrogen-fixing properties of the bacteria in their root nodules.

(3) A creeping plant which will root at the nodes and thus spread over a large area of ground is desirable.

(4) A plant which will entwine and smother grasses and other weeds is to be preferred.

(5) The plant should be easily established from seed and make rapid growth.

(6) It should have a well-developed root system to aerate and bind the surface soil.

(7) It should have a luxuriant foliage to provide an effective protection to the soil from heat and rain, and to provide a plentiful leaf mulch.

(8) It should not be subject to diseases or pests liable to attack *Hevea*.

A considerable number of leguminous species fulfil these conditions, and it is unnecessary to look beyond this family for suitable covers. For new clearings the most suitable and extensively used covers are *Dolichos Hosei* (*Vigna oligosperma*), *Centrosema pubescens*, and *Calopogonium mucunoides*. These three covers are all easily established from seed, and *Vigna* is also often propagated by means of cuttings. Under favourable conditions these species will rapidly form an extensive cover tending to choke out grasses and other weeds. *Vigna* and *Centrosema* form permanent covers in that they will grow well in the increasing shade of the maturing rubber. *Calopogonium*, on the other hand, although perhaps the best of all plants for establishing a quick cover on newly-opened land, is intolerant of shade and dies out as the rubber grows older. It should therefore, always be mixed with a cover of greater permanency.

A plant which is of more recent introduction to Ceylon and which gives excellent promise is *Pueraria phaseoloides* (*P. javanica*). This forms a dense cover similar to *Calopogonium mucunoides*, though more easily controlled, and appears to thrive equally well on new and old areas. It is planted extensively in Malaya and the Dutch East Indies.

Indigofera endecaphylla forms a compact cover which is easily kept under control, but is not very effective in keeping down weeds. It is readily established from seed or cuttings

and flourishes on a good moist soil. *Indigofera* requires a fair amount of humus, however, and is therefore not easily grown in badly washed areas. It has been tried as a cover under old rubber in Ceylon and Malaya but with little success.

In Java, Sumatra, and Malaya, *Mimosa invisa* has been used extensively on new clearings, and its value in improving poor soils is very marked. It dies out, however, under heavy shade. There are two important objections to its use: (1) the risk of fire in dry weather, and (2) the damage to coolies' feet owing to its thorny nature. In Ceylon *Mimosa invisa* has been regarded as a potentially serious weed on waste or chena lands, and has not been introduced.

Many other species have been tested by the Department, and some of these form excellent covers in new clearings. Amongst these are: *Desmodium* spp., *Centrosema plumieri*, *Dunbaria Heynei*, *Phaseolus radiatus*, etc. Although not used extensively in Ceylon at the present time these plants are worthy of trial on estates.

(b) *Erect Green Manures.*—The most important characteristic of a good green manure plant is that it should provide large quantities of nitrogen and organic matter for the soil. This is mostly supplied by periodically cutting back the plants and burying the loppings. When turned into the soil the green material not only increases the humus content, but, in the process of decomposition, also has the effect of rendering some of the mineral constituents of the soil more readily available as plant foods. Species vary in the extent to which they may be pruned without permanent detriment to their growth, and the ideal cover must clearly be able to stand periodical severe lopping.

As with creeping covers there is a wide range of leguminous plants which can be employed for this purpose. *Tephrosia candida* (Boga medeloa), *Clitoria cajanifolia*, *Crotalaria usaramoensis*, and *Crotalaria anagyroides* are the most extensively used green manures on new clearings in Ceylon.

Tephrosia candida has been a favourite green manure in the East for many years, and grows well on almost all types of soil and at all elevations. It produces a very large quantity of green material from prunings and fallen leaves. The plant is not, however, very tolerant of severe pruning and should be cut back lightly at relatively frequent intervals. *Tephrosia* should be cut out and replanted after two or three years owing to the fact that, on account of its woody habit, it is liable to attack

Crotalaria usaramoensis

Dolichos Hosei (Vigna) under old rubber

by "pink disease" (*Corticium salmonicolor*), and by the root diseases caused by *Fomes lignosus* and *Fomes lamaoensis*. *Tephrosia candida* and *Clitoria cajanifolia* are commonly planted in hedges, and are thereby useful as preventives of soil movement in addition to their green manurial properties.

Clitoria cajanifolia is an excellent species for permanent hedge planting. It does not provide so great a quantity of green leafly material as *Tephrosia*, but has the advantage that it may be repeatedly lopped without becoming excessively woody. Recent experiments by Holland [8] have shown that hedges of *Clitoria* are very effective in checking soil erosion.

Crotalaria anagyroides and *Crotalaria usaramoensis* are usually sown broadcast on new clearings in conjunction with ground covers, and both provide a large quantity of leaf mulch. The former species grows to a larger plant than the latter, and is preferable on account of its quicker growth and exceptionally deep-root system. Both species propagate abundantly by self-seeding, but neither are tolerant of severe lopping.

A plant which has not been used extensively in Ceylon, but which has given a favourable impression on the Rubber Research. Scheme Experiment Station, Nivitigalakele, is *Desmodium gyroides*. This grows quickly to a large bushy shrub and provides a good weight of green material.

Amongst other species which have been used and which new clearings in the Dutch East Indies. It is kept lopped at a height of about 2 feet and is stated to stand periodical pruning better than any other species.

Amongst other species which have been used and which are worthy of trial are: *Desmodium heterocarpum*, *Indigofera arrecta*, *Crotalaria striata*, *Sesbania cannabina*, *Tephrosia vogelii*, *Tephrosia noctiflora* etc.

(2) MIXTURES OF COVER PLANTS

It is clear from the foregoing remarks that both types of cover plants, i.e., ground covers and erect green manures are necessary on new clearings. Although some species of green manures are usually planted in hedges it is a sound practice to broadcast a mixture of seeds of both types so that the various species grow up together. The erect covers then provide the small amount of shade beneficial to the young seedlings of some of the ground covers. Instances are known in which *Dolichos Hosei* was quickly established in this way, whereas by sowing the seed by itself on exposed soil the plant made little progress.

It is found that certain cover crops which make rapid growth at first gradually die off, whereas others, which are less quickly established, are of greater permanency. It is, therefore, desirable to plant a mixture of these two types so that the more permanent cover may, in course of time, replace that which made the earliest growth. Thus *Calopogonium* should be planted in conjunction with a cover such as *Dolichos Hosei*, *Centrosema pubescens*, or *Pueraria phaseoloides*. The *Calapogonium* will provide most of the cover during the first year or two, and this gradually be replaced by the other species which flourish in the shade of the maturing rubber.

(3) METHODS OF PLANTING

In planting up a new clearing with cover crops and green manures the most important consideration is that the ground should be covered as soon as possible after felling and burning the timber so as to prevent the loss of surface soil and humus consequent upon exposure to the tropical sun and rain, and to keep weeds in check. At the same time, whether seeds or cuttings be used, it is valueless to attempt to plant a cover in settled dry weather, and the planting operations should always be carried out when wet weather can be expected. The ideal condition for planting is, therefore, when a spell of wet or showery weather follows a few weeks after the timber is burned. In the main rubber-growing districts of Ceylon it is usually arranged that the "burn" takes place in January or early February, and every effort should be made to "smother" the land in cover crops during the rains commonly experienced in April.

Whether seeds or cuttings are to be used, the first essential is to clear the area of weeds, and subsequently to carry out a regular weeding programme until the cover is thoroughly established. It is the general experience that if the eradication of weeds is rigorously carried out while the cover is becoming established, the thick cover that subsequently develops chokes out weeds to a great extent and enables hand weeding to be carried out at a greatly reduced cost.

All the species recommended above are best planted in new clearings from seed, and unless for some reason seed is not available there is no necessity to propagate vegetatively. Seed of the various species selected should, as a general rule, be mixed, and for quick germination may be soaked for 24 hours in warm water immediately before planting. Seed treated in this way must on no account be allowed to dry out before sowing. The seed may be planted in small holes two or three

seeds to a hole, scattered irregularly throughout the area, or may be distributed in rows on loosened soil and pressed well down. The distance apart of the rows or holes and quantity of seed per acre naturally depends on the species used.

When it is necessary to propagate from cuttings care must be taken to use only mature stems, and to press these well down into the soil to prevent them drying out. A useful method of procuring rooted cuttings is to embed split coconut shells (*sheraties*) in the nursery beds before planting seeds, and to plant these out in the field when the nursery is well established.

Some species of erect green manures are best planted in hedges, thereby forming valuable checks to soil movement. These hedges should be planted along the contours, their position depending to some extent on the method of opening.

In Java and Sumatra soil erosion is largely prevented by silt-pits, the earth from which being used to build continuous ridges about one foot high immediately above the pits. The ground cover is commonly planted on these soil erosion ridges.

On poor soils the establishment of leguminous species may be materially assisted by the application of manure at the time of planting. Phosphoric acid is the chief requirement, and this is probably best supplied by basic slag. Bulk cattle manure is often used when available. The manure should be mixed with good surface soil and planted with the seed.

(4) SUBSEQUENT TREATMENT

In order that the maximum benefit from cover crops may be obtained it is not sufficient simply to plant them and ensure their vigorous growth. Erect covers are grown as sources of green material, and in order to obtain the maximum quantity of humus the plants must be periodically pruned.

The extent and frequency to which the bushes should be cut back varies with the different species, but in general it is advisable to lop twice a year. In determining the time of year at which lopping should be undertaken a number of factors must be taken into consideration. In order to obtain the maximum quantity of food substances the plants should be lopped when in full bloom, before the seed has been set. On the other hand the seed may be required for further planting. The plants should not be pruned in dry weather. If possible lopping should be undertaken in showery weather at the end of a monsoon, so that the green material is buried in a moist soil. The plants will then have made a small renewed growth before the succeeding spell of dry weather, but will not take much moisture from the soil.

The correct treatment of the loppings provides a debatable problem. There is no doubt that in order that the soil should derive the greatest benefit by the addition of nitrogen and humus-forming material, the loppings should, in some way, be turned into the soil. Joachim [4] has shown that if green material is allowed to dry on the surface of the soil nearly 50 per cent of the nitrogen may be lost. Where possible, therefore, green manure loppings should be forked into the soil or buried in pits, and it is probably advisable to alternate these two methods. Where expenditure must be reduced to a minimum it is customary to spread the loppings behind the bushes, or, where platform planting has been adopted, at the back of the platforms.

The extent to which ground covers should be kept back from the young rubber plants is, again, a debatable point. On the one hand the growth of covers in close proximity to the young plants will result in slower growth owing to competition between the rival root systems for plant foods and moisture, and on the other hand any bare soil will tend to deteriorate as the result of exposure to a hot sun and heavy rain. It is clearly necessary at first to maintain a small area around each young plant free from any ground cover on account of the danger of a cover with a twining habit climbing up the rubber plants and smothering them. As the root system of the rubber spreads so this cleared area should be kept larger and larger if competition between the roots is to be avoided. The logical outcome of this treatment, however, would be the eventual removal of the entire cover, thus returning to the policy of clean weeding. It is clear that a compromise must be effected. Observation in Ceylon and other countries has shown that the growth of young plants is definitely retarded by the presence of a close cover, and it is therefore probable that an area corresponding approximately to the spread of the root system should be kept clear around each plant until the rubber is approaching tappable age. Where the platform system of planting has been adopted it is simple to keep the platforms wholly or partly clear of any green manures or cover plants while the rubber is between the ages of about 2 to 5 years. Where the rubber plants are very young a cleared area corresponding to the size of the holes is sufficient, and when the rubber is mature the cover may, with certain limitations, be allowed free scope.

It has been found that on areas planted with a mixture of ground covers and erect green manures, the former tend, after two or three years, to somewhat smother the latter. It is therefore, necessary to re-establish the green manures periodically.

(5) WIND-BREAKS

Although wind-breaks do not strictly come under the category of green manures, in that their primary function is not concerned with soil improvement, by the selection of suitable species, many of the benefits associated with green manure plants may also be obtained. By planting leguminous species the soil is enriched by the fixation of atmospheric nitrogen, and by selecting varieties which not only give effective protection against the wind, but which may also be lopped to yield green material, the dual functions of wind-breaks and green manures are fulfilled.

Young rubber plants are very susceptible to strong winds, and their growth may be materially retarded or even completely inhibited when planted in exposed situations. On clearings which are at all exposed to wind, it is therefore necessary to protect the plants as far as possible by the establishment of wind-belts. In the past the use of wind-breaks on new clearings has not received its merited consideration.

One of the most effective wind-break trees is *Albizzia moluccana* which grows very rapidly and has a deep-root system, On new clearings it should be planted as early as possible along the ridge of all exposed hills, the establishment and rapid growth of these trees being at first regarded as of equal importance to the growth of the rubber plants. A row of *Albizzias* planted lower on the slope of a ridge at right angles to the direction of the prevailing wind is also of great value in deflecting the wind above the top of the ridge. *Albizzia* grows with a spreading habit and quickly forms a substantial wind-belt. It is a matter for discretion whether the trees should be removed when the rubber is approaching maturity, or whether they should be retained permanently. Mature rubber has been seen growing excellently in conjunction with large *Albizzias*, and it is possibly of advantage to retain these trees in particularly exposed areas.

Albizzia may also be planted between the rows of rubber both for wind protection and as a source of green manure, but it must be kept pruned so that the young rubber trees are not overshadowed or "spindly" development of the latter will result. Pruning must, however, be undertaken with discretion so that the rubber trees are not left without protection when

high winds are prevalent. *Albizzia* can most conveniently be grown from seed in nurseries, and thence planted out in the field.

In addition to the establishment of major wind-breaks *Gliricidia maculata* may be planted in rows at right angles to the direction of the prevailing wind. If kept lopped at a suitable height this species gives valuable protection to the young rubber plants in the first two or three years, and also provides a great quantity of green manure. *Gliricidia* is most easily planted in the form of cuttings about 6 feet in length.

Dadap, *Erythrina lithosperma*, is also commonly planted in young clearings as an alternative to *Gliricidia*. In certain localities it thrives better than the latter. It is easily established from cutings or seed; grows rapidly, and is valuable as a source of green material.

Leucaena glauca grows to a small tree 15 to 20 feet in height and forms a useful wind protection for young rubber. Subsequently it may be cut low and retained as a green manure hedge. It must be stated, however, that this plant has shown indifferent growth at the Rubber Research Scheme Experiment Station.

IV GREEN MANURES AND COVER CROPS UNDER MATURE RUBBER

The value of green manures and cover crops in re-conditioning badly washed soil under old rubber was recognised some years before the establishment of such plants became a general custom. This delay in adopting an obviously sound agricultural practice was due, not only to the conservative attitude of many influential planters, but also to the difficulty in finding suitable species which could be easily established and retained in heavy shade. The earliest efforts towards checking soil erosion and providing mulch consisted of "selective weeding", whereby certain weeds thought to be noxious were eradicated and other harmless species retained. When certain leguminous plants were found to be tolerant of the normal shade under mature rubber it was clearly preferable to substitute the mixed weed growth by a leguminous cover, thus obtaining the additional soil enrichment due to the activities of the nitrogen-fixing bacteria in the root nodules characteristic of the family.

The influence of a ground cover on the growth of weeds has always provided a basis for argument between the respective advocates of clean weeding and cover crops. It was at first feared that the existence of a cover would increase the

difficulties and therefore the cost of weeding. It has been the general experience, however, that provided the ground is rigorously weeded, while the cover is establishing itself, a thick cover will subsequently be formed which will tend to choke out weeds and thus enable hand weeding to be carried out at a reduced cost. If, on the other hand, weeds are not kept in check while the cover is still thin, a mixed growth will result and the eradication of the undesirable species may present considerable difficulty.

(1) CHOICE OF SPECIES

The choice of species for use under mature rubber is less extensive than for new clearings. As far as ground cover is concerned it is essential that the plant should be easily established, and should be of a permanent nature. The number of leguminous plants fulfilling these conditions under the shade of mature rubber is relatively limited. As regards erect green manures the same limitation is experienced, and the possibilities of supplying mature rubber areas with green manure are as yet largely unexploited.

(a) *Ground Covers.*—One of the earliest ground covers to be used was *Mimosa invisa*. This is probably unsurpassed on badly washed soils where the foliage of the rubber trees is scanty, and many areas in the Dutch East Indies have been greatly improved by the use of this cover. *Mimosa* will not, however, grow under heavy shade, and there are various objections to its use which have been considered of sufficient importance to bar its introduction to Ceylon.

An important advance in the use of cover crops in rubber cultivation was made when it was discovered that *Dolichos Hosei*, the Sarawak bean, flourished in the normal shade of old rubber. (*Dolichos Hosei* is universally known to planters in Ceylon as *Vigna* (*oligosperma*); to avoid confusion the latter name will therefore be employed). This species was the earliest ground cover to be planted extensively in mature areas, and has remained up to the present time the only important cover in Ceylon. *Vigna* is easily grown from seed, but since seed is somewhat expensive, it is preferable to establish a nursery, and thence to plant out cuttings in the field. The plant has a comparatively shallow rooting system and is, therefore, probably of greater value on flat and undulating land than on steep hill slopes. *Vigna* has, nevertheless, proved invaluable in checking soil erosion in hilly districts in Ceylon, the clearness of the drainage water bearing adequate testimony to its efficacy.

It is also valuable as a soil builder, and under a thick cover of *Vigna* a quantity of leaf mulch is always to be found. In addition to the soil benefits due to ground cover it has been the general experience in Ceylon that a cover of *Vigna*, by inducing moist atmospheric conditions and keeping the ground temperature low, is beneficial to the flow of latex so that late tapping does not result in so great a diminution of yield.

In Java and Sumatra *Vigna* has, of recent years, been largely replaced by *Centrosema pubescens*. This forms a very similar cover to *Vigna*, but is probably to be preferred on account of its deeper root system, its marked twining habit which makes it very effective in choking out weeds, and its ability to withstand prolonged periods of dry weather. *Centrosema* is, however, more difficult to establish in shade than *Vigna*, and at first makes slower growth. Efforts to establish this plant under mature rubber have been made on many estates in Ceylon, but except where the shade is light very little success has been obtained. *Centrosema* requires a fairly good soil, and it is probable that the poverty of eroded Ceylon soils, in conjunction with heavy shade, is largely responsible for the different experiences with this cover in Ceylon and Java. It seems likely, however, that once established on a new clearing *Centrosema* will persist when the trees become mature.

Centrosema plumieri has been seen growing under mature rubber where the shade is light, but this species is no more tolerant of heavy shade than *C. pubescens*, and is generally regarded as inferior to the latter in other respects.

Pueraria phaseoloides (*P. javanica*) has only recently received attention in Ceylon, but promises to be of considerable value under mature rubber as well as in new clearings. Although growth is somewhat slow at first a dense cover is eventually obtained. *Pueraria* has been planted extensively in Malaya and the Dutch East Indies, and in Ceylon may prove to be a useful substitute for *Vigna* where the latter has died out.

Various indigenous species of *Desmodium* grow well in old areas in Ceylon. *Desmodium triflorum* is a very small-leafed species which forms a close mat over the ground. It is effective as a preventive of soil erosion, but its close "mat-like" growth is an objection. It is not to be recommended where other covers can be grown. *Desmodium heterocarpum* is a sub-erect woody plant which is, perhaps, of more value as a source of green manure than as a ground cover. It is grown extensively in south India under the synonym *Desmodium polycarpum*.

(b) *Erect Green Manures.*—As regards erect green manures the ideal plant for mature areas has yet to be found. Most of the leguminous species which flourish on new clearings produce, but a stunted growth in heavy shade. There is no doubt, however, that humus is the most important soil requirement of the average rubber estate in Ceylon, and the establishment of green manures in addition to cover crops is therefore much to be desired.

Tephrosia candida grows rapidly under mature rubber, and, although not attaining its full development under shady conditions, is a valuable source of green material. The plant, however, must be periodically re-established, not only because it weakens under the shade, but also because when woody it is liable to attack by some of the root diseases fungi to which *Hevea* is prone.

Crotalaria anagyroides and *Crotalaria usaramoensis* will both grow in old areas, but, if an adequate supply of green material is to be maintained, they must be frequently replanted. Both species grow more rapidly than *Tephrosia*, but are less tolerant of lopping. They produce seed in great abundance in open areas or where the shade is light.

It is suggested that *Gliricidia maculata* would be of great value as a green manure if planted between the rows of trees. Further experience is necessary, however, before this species can be definitely recommended.

(2) METHODS OF PLANTING

The greater part of the ground cover of *Vigna* under mature rubber in Ceylon has been planted from cuttings. Owing to the fact that the plant is a shy seeder, seed is relatively expensive, and the establishment of *Vigna* by seed over a large area would be a costly proceeding. Where cuttings are not readily available from neighbouring areas it is, therefore, advisable to establish nurseries from seed and thence to plant out cuttings in the field. After cuttings have been removed from the nursery a new flush of growth will take place so that in a few months further cuttings may be taken. A useful method of procuring rooted cuttings is to embed split coconut shells in the nursery beds before sowing, and to plant these out in the field when the nursery is well grown.

Provided that good soil is selected and weeds are eradicated there is no difficulty in establishing a good nursery of *Vigna* in a short space of time. In transferring the cover to the field, however, considerable trouble is often experienced in certain areas. It has been the experience of many planters that whereas a thick cover is easily established on the greater part of the estate, certain areas are apparently unable to support the cover. This is usually due to the absence or scarcity of the particular bacteria without which the plant is unable to make vigorous growth. In such cases large mats of *Vigna* should be planted together with a quantity of the soil in which they were growing. The "barren" soil is thus inoculated with the necessary organisms, which multiply rapidly as humus is formed. The split coconut shell method of planting (described above) is also useful in such areas.

Centrosema pubescens is best established from seed. Germination usually takes place within 10 to 14 days of the time of sowing, but the growth of the seedling is slow, and on most Ceylon soils under heavy shade the plant makes little progress. According to a recent report [5] very successful results have been obtained in Sumatra by soaking the seed in an extract of crushed *Centrosema* root nodules, thus securing the inoculation with the necessary bacteria. This method might also be useful where difficulty is found in establishing *Vigna*.

Owing to the scarcity and cost of its seed, *Pueraria phaseoloides* is most satisfactorily grown from cuttings. If mature stems about 2 feet long are used the plant roots very readily. Growth is somewhat slow at first, but eventually a thick cover is obtained.

The establishment of ground covers on poor soil is materially assisted by the application of small doses of manure. Phosphate is the most important requirement, and basic slag appears to be the most suitable source. The addition of a small proportion of nitrogen is also beneficial, and excellent results on a thin cover of *Vigna* have been obtained with ammonium phosphate. Cattle manure, when available, has also been found useful for starting a cover.

Under mature rubber erect green manures are probably most beneficial when grown in hedges along the contours. In addition to their green manurial properties they are then valuable as checks to soil movement. It must again be stated that in Ceylon very little use has been made of such plants in mature areas, and that such planting as has been undertaken has been somewhat haphazard in nature.

Tephrosia candida and *Crotalaria* spp. should be sown thickly in rows along the contours midway between the rubber trees. Care must be taken that the growth is not too close to the trees, or the drying of the tapping cuts after rain will be seriously retarded by the damp atmospheric conditions caused. Haphazard planting will also result in interference with the supervision of tapping.

(3) SUBSEQUENT TREATMENT

There is no general agreement as regards the correct use of cover plants under mature rubber, and further investigation is required on many points. In Ceylon it is customary to allow *Vigna* to form a complete cover over the whole estate, a small circular area being sometimes kept round each tree to aid in the detection of root disease and collar rot. Although by this means soil erosion is very effectively prevented, it is argued by some that the cover competes with the rubber trees for moisture and food substances, heavy toll being taken of any manure which may be applied. It is thus the practice on some estates in Java and Sumatra to confine the cover to the soil erosion ridges, reliance being mainly placed on the latter for the prevention of soil wash. Although this method may be suitable on flat or gently undulating ground, it would seem that on the steep hillsides on which *Hevea* is commonly grown in Ceylon a complete cover is preferable. In such cases the only limitation to the growth of a ground cover is the presence of root disease. In areas where root disease, particularly *Fomes lignosus*, is known to be present, it is important that the ground should be kept strictly clean weeded.

In order to obtain the maximum benefit from a ground cover it is not sufficient simply to ensure its establishment and vigorous growth. Although experiences differ with regard to the direct effect of green manuring on latex yield, there can be no doubt that the soil is materially improved by the addition of humus-forming tissues so that an increased crop will eventually result. A ground cover adds a certain quantity of humus to the soil by reason of its normal leaf-fall, but in the process of decomposition on the surface a large proportion of the available nitrogen escapes into the air in the form of ammonia and is lost to the soil. In order that the soil should reap the maximum benefit, it is, therefore, necessary that the cover should be periodically buried in the green state.

It must be stated that it is not at present customary on Ceylon estates to utilise the ground cover as a green manure. Where artificial manures are applied to ground bearing a thick cover the latter is usually rolled back from the strips or squares to be manured, and either left as "bunds" or replaced on the surface of the ground. There can be no doubt that from the agricultural view-point this is not the ideal method, and that the opportunity of incorporating valuable green material with the soil is lost. Alternative methods of incorporating the cover with the soil are: (1) forking, and (2) burying in pits, and the choice of these two methods is largely dependent at present on individual preference. Where artificial manures are being applied by envelope-forking the cover can be torn up and forked into the furrows together with the manure. With certain mixtures the cover is often killed, but in course of time the ground is usually again covered by encroachment from the unmanured strips. An objection advanced against envelope-forking the cover into the soil is that the feeding roots of the rubber are thereby disturbed and damaged. There is, however, no doubt that forking is itself beneficial in certain areas, and in choosing the method of utilising a cover the planter must be guided by the condition of the soil in question. Burying the cover in pits has the obvious objection that the green material is thereby less evenly distributed so that the soil loses some of the benefits due to the humus formed.

Another method has been adopted on some estates where the expense of forking has been considered unjustified. The cover is rolled back in strips like a carpet and replaced on the ground upside-down. Although this method is doubtless of some benefit, a large proportion of the nitrogen and organic matter is lost.

Whatever method of utilising the ground cover may be adopted, it is clearly inadvisable on hilly ground to remove the entire cover at one time. Strips of cover should be retained along the contours so that the ground is not left entirely unprotected against soil erosion.

In addition to the soil improvement consequent upon the incorporation of green material, there is another important reason why the periodical disturbance of a ground cover is

desirable. It has been a common experience in Ceylon that healthy covers of *Vigna* have unaccountably died off after four or five years of growth. Although the depredations of the Kalutara snail (*Achatina fulica*) have been responsible for considerable damage, there can be little doubt that in many cases the death of the cover has been due to a soil factor which, for want of more exact terminology, is called "staling". The disturbance, aeration, and enrichment of the soil consequent upon periodically turning in a green cover helps to enable the soil to maintain a fresh growth of the same plant. Ground which has become "stale" should be rested before endeavouring to re-establish a cover, and a different species should, if possible, be used on such areas.

Although a ground cover in addition to its value in the prevention of soil erosion, can be utilised to provide green manure, a considerably larger bulk of green material can be obtained by growing shrubby leguminous plants and periodically turning them into the soil. There can be no doubt as to the theoretical value of such a procedure, but there is a great diversity of opinion among practical men as to the economic aspects of growing erect green manures under old rubber. In the first place such species as have so far been used are somewhat difficult to establish and costly to maintain. In order that the soil may derive the maximum benefit, the plants must be lopped frequently, and the loppings forked into the ground or buried in pits. Although forking is undoubtedly beneficial to some soils, its frequent practice is open to objection on account of the damage caused to the rubber roots. It is argued by many planters that the money spent on the establishment and utilization of such plants could be more usefully employed in providing artificial manures. It must be borne in mind, however, that inorganic manures cannot cause any permanent improvement in the chemical and physical condition of the soil unless humus is also present. Artificial manuring should, therefore, be combined with green manuring.

A judgment as to the economic value of growing green manures in old areas must await the outcome of further experiments and field experience. An important advance will be made when a species is revealed which is easily established and maintained under the normal soil and shade conditions of mature rubber areas.

LIST OF SPECIES MENTIONED

Albizzia moluccana
Calopogonium mucunoides
Centrosema Plumieri
Centrosema pubescens
Clitoria cajanifolia
Crotalaria anagyroides
Crotalaria striata
Crotalaria usaramoensis
Desmodium gyroides
Desmodium heterocarpum (*D. polycarpum*)
Desmodium triflorum
Dolichos Hosei (*Vigna oligosperma*)
Dunberi Heynei
Erythrina lithosperma (Dadap)
Gliricidia maculata
Indigofera arrecta
Indigofera endecaphylla
Leucaena glauca (Lamtoro)
Mimosa invisa
Phaseolus radiatus
Pueraria phaseoloides (*P. javanica*)
Sesbania cannabina
Tephrosia candida (boga medeloa)
Tephrosia noctiflora
Tephrosia vogelii
Vigna (see *Dolichos Hosei*)

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SECTION IV

GREEN MANURING OF COCONUTS

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THE practice of green manuring on coconut estates, though, gradually extending, is not as popular as it might be. The reasons for this appear to be threefold. Firstly, the value and advantages of green manuring in the tropics are not sufficiently well understood and, where realised, the practice is not adopted either through lack of funds or from general apathy, the policy on many coconut estates being apparently to let well alone until periods of low prices compel estate owners to take some measures to increase crop yields. Secondly, coconuts are not generally cultivated on hilly land but on flat or undulating land, in many cases under grass. The adoption of measures for the prevention of soil erosion, of which the planting of cover crops is one of the most effective, is therefore not rendered so imperative if the estate is to be saved from deterioration, as on tea and rubber estates. Finally, in a large portion of the coconut area in Ceylon the soils are very light and sandy with low water-retaining capacities and the rainfall is comparatively low. Soil moisture, therefore, becomes the limiting factor of crop growth in these districts. The fear is thus entertained that by the growth of cover crops and green manures the coconut will be deprived of the little moisture present in the soil during periods of drought.

The systematic green manuring of coconut estates in Ceylon has only been recently undertaken, and the practice is far from being general. Individual estates are, however, carrying out useful work on the subject. In the Dutch East Indies and the Philippines it is extensively practised on European and American owned plantations. In Malaya conditions are similar to those in Ceylon. In general, coconut estates in Ceylon on which green manuring has been adopted, as it should be, have reported favourably on the results obtained, and neglected properties for years under grass are being brought into condition by cultivation and green manuring. Green manuring is not only practicable in all the coconut districts of the Island but

also essential if yields are to be appreciably increased at a comparatively small cost. The advantages resulting from the practice are so many that if only they are brought home to coconut planters, universal adoption of the practice is bound to follow.

The term "green manure" is employed in its widest sense to mean the use of plants and plant material, leguminous as well as non-leguminous, for incorporating into the soil or as cover crops.

The advantages of green manures which have already been fully explained in Section I on the principles of green manuring, may, at the risk of repetition, again be summarised:

(1) Green manures when used as cover crops prevent soil erosion, improve the physical condition of the soil and increase its water-holding capacity, and reduce weeding costs.

(2) By ploughing in green manures large quantities of organic matter, so deficient in tropical soils, available nitrogen, potash and phosphoric acid are supplied to the soil. It is reckoned that with a crop of 4 tons per acre, containing on an average 20 per cent of dry matter and ·6 per cent of nitrogen, about ·8 tons of organic matter are added to the soil and about 35 lb. of nitrogen are made directly available to the crop.

(3) Most green manures can be used as fodder.

In contrast to the advantages derived from green manuring, the disadvantages of present-day estate practice where neither green manuring nor artificial manuring is adopted will be apparent and need little elaboration. Estates on which only regular ploughing is carried out are bound sooner or later to have their yields fall to a very low level, owing to the exhaustion of the soil organic matter which is so closely connected with soil fertility.[6]

Estates on which no cultivation whatever is carried out, no weeding is done, and no measures taken to prevent the loss of soil moisture during drought or of the surface soil during heavy rains if the land is undulating, will necessarily give low yields. Estates left under grass and which are uncultivated are generally reported to yield well. This is probably because of the accumulation of organic matter and nitrogen under uncultivated grass.[7] There is little doubt however that grass has some detrimental effect on yields and it is more than probable that if it were replaced by a leguminous cover crop, higher yields would be obtained. Grass can affect coconut palms adversely by depriving the latter of some of the soil moisture, by causing the surface soil to get "bound" and so preventing

good soil aeration and the absorption of the rain water, by increasing the carbon dioxide content of the soil air and by assimilating the available nitrate of the soil as well as a part of the manure applied to the crop. On hilly and undulating land grass will prove useful against soil erosion, but its disadvantages may counterbalance any advantages accruing therefrom.

PRACTICAL CONSIDERATION ON GREEN MANURING COCONUTS

Under this heading will be discussed the soil and climatic conditions under which green manuring of coconuts can be carried out, and the treatment of green manures in various coconut districts.

Soil and climatic conditions determining the adoption of green manuring.—The greater part of the coconut areas of the Negombo, Chilaw and Puttalam districts consists of light sandy soils markedly deficient in organic matter. The rainfall conditions are not ideal, especially in the Puttalam district and long periods of drought are not unknown. The question may well be asked: Will not the light soils of these areas be deprived of the little moisture they contain by the growth of green manures ? The results of investigations carried out at Peradeniya on this question have shown that once cover crops have been well established, more moisture is found in the soil after a period of drought than in bare soil or in one in which such crops are not grown.[6] In the case of bush green manures it has been found that, from the point of view of soil moisture, lopping before the drought sets in is essential and that forking the loppings into the soil towards the end of the rains is distinctly advantageous.

Provided there is sufficient rainfall, green manures can be grown with advantage even on poor sandy soils. In such a case, growing a green crop and turning it in will eventually increase the water-holding capacity of the soil and enrich it with nitrogen and humus.

The treatment of green manures, especially in the season prior to drought.—In order to secure maximum amounts of nitrogen and optimum decomposability, bush and creeping green manures should be cut just before flowering. In the case of the former care must be taken that the branches do not get too woody before they are lopped as the more woody they become the more resistant they are to decomposition.

But in dry districts particularly, green manures should be cut towards the end of the rainy season when the showers alternate with dry weather, and should be ploughed in at once. On sandy soils in districts where a long drought follows the rains, if it has not been found possible to turn in the loppings, these should be cut at the commencement of the drought and left as a mulch on the surface. On these soils moisture and not nitrogen is often the limiting factor of crop growth, and the mulch of green material will form a useful means of conserving soil moisture. It is preferable, however, to turn in the cuttings about three to four weeks before the drought sets in, as by that time a certain amount of decomposition will have taken place and the decomposed material will have been able to retain some moisture for the subsequent use of the crop. On no condition should green manures be cut and forked into the soil during a drought, even at the beginning of it. This applies particularly to light sandy soils. The decomposition of green manures does not take place if the soil has insufficient moisture at the time of burying or subsequently. If they are ploughed in during dry weather when the soil is dry, the material remains undecomposed and leaves large air spaces that cause loss of water by evaporation. It may be necessary in some instances to compact the soil after green manuring in order to minimise the losses of soil water and to establish capillarity in the soil.

In districts of average quality soil and with average rainfall the general treatment of cover crops under coconuts before a drought is a comparatively simple matter. Most covers die down during a prolonged drought, and the decayed leafy material obtained forms a very good mulch. If, in addition, light disc-harrowings are periodically given, the palms should not be affected to any great extent by drought. Immediately the rains start, the cover crops come up again. In the case of those covers which stand drought well, experiments at Peradeniya indicate that once the cover has been well established less moisture is lost from the covered area than from the bare soil. In districts with a good rainfall, though some moisture will be lost from the soil through cover crops in the early stages of their establishment, there will not be any permanent ill-effects on old coconuts. In young plantations it would perhaps be useful to grow a mixture of drought-resisting and non-resisting covers. Where the soil is sandy and rainfall good and evenly distributed, the growing and forking in of quick-growing annual covers (such as cowpeas and *Mucuna*) are advised; and when the soil is sufficiently enriched with organic matter, this should

be followed by the establishment of a more permanent cover. In the case of sandy coconut soils in dry districts quick-growing annual crops should be established in the rainy season and ploughed in towards the end of the rains. Boga medeloa or other bush green manure should also be grown and the loppings cut and left as a mulch on the surface at the beginning of the drought. After a few years of this treatment, the question of the establishment of a permanent cover should be considered.

It is necessary to emphasise the point that cover crops must periodically be turned into the soil. It has been observed that on estates where cover crops had been established they have often been allowed to get quite out of hand, no agricultural treatment whatever having been given since the establishment of the cover crops. In some cases the cover crop had grown to a height of from 2 to 3 feet and had even climbed up the trunk of the palms. Further, on many of the estates no artificial manuring whatever had been done since the covers were first planted. On estates which had been manured, the manures had often been either broadcasted over the cover or forked around the palms clear of the cover and the latter allowed to grow over the manured areas. Sometimes cover crops and green manures had been established on areas fertilised with a mixture intended for the coconuts. The impression seemed to be fairly general that green manuring meant merely the growing of leguminous cover crops and not their incorporation into the soil. A warning must be issued against such misunderstanding of the process of green manuring which, instead of producing any results of value, would only cause a setback to the crop.

Green manuring is the practice of *turning into the soil* undecomposed plant material with the object of increasing soil fertility. If the green manure is a leguminous cover crop, the turning in of the green material will add to the available nitrogen content of the soil, as practically all leguminous crops fix free nitrogen in the nodules present on their roots. Some of the nitrogen so fixed in the nodules is steadily transferred to the leaves and stems, and therefore, unless the green material is incorporated with the soil, the main crop would get comparatively little benefit from the nitrogen so fixed. In regard to potash and phosphoric acid it has to be emphasised that green manure crops take the whole of their needs of these constituents from the soil. Unless the green manure crop is turned in, it would therefore be depriving the main crop of some of the available

phosphoric acid and potash present in the soil. As phosphoric acid and potash are the chief manurial ingredients required by the coconut palm for good yield production, there is little doubt that on estates where these fertilisers are not applied, the cover plants are bound in time adversely to affect yields, unless they are systematically incorporated into the soil. In fact, estates are known on which cover crops have been grown for some years now, but to which latter no treatment whatever has been given, and the results have been disappointing. This is not in the least surprising. On the other hand, by turning cover crops into the soil, the phosphoric acid and potash assimilated by them is returned to the soil in an easily available form, with obvious benefit to the main crop.

From an economic point of view, by the growth of green manures and the practice of green manuring on coconut estates weeding costs are reduced and a free source of organic nitrogen is obtained. The manure bill can be very appreciably reduced by eliminating all organic nitrogen from it. Any nitrogen added, where required, should be in the form of cheap artificial nitrogenous manures. But green manuring cannot obviate the necessity for the application of potassic and phosphatic fertilisers to coconut. It is essential that on green manured coconut estates potash and phosphoric acid be applied, and preferably in larger quantities than those normally required by the crop.[5]

On some estates the manure mixture is broadcasted over the cover crop. This is obviously a practice to be avoided wherever possible, as a great deal of the manure intended for the main crop will be taken up by the green manure crop even temporarily. Further, if the mixture contains artificial nitrogen, a leguminous crop will make no attempt whatever to fix free nitrogen, which it would otherwise do. Broadcasting of artificial manures over a cover crop is advisable only when the cover is to be turned in immediately after. The practice of growing leguminous green manures on fertilised areas is also to be discouraged for the reasons just stated.

In regard to all coconut manuring it has to be remembered that manures are applied for the benefit of the main crop, and that green manuring is for the same purpose. If, therefore, the manuring is so carried out that the cover crop gets the chief benefit of the manures applied, and if the cover is left unturned into the soil for long periods, it cannot be expected that the main crop will derive an appreciable advantage for the expenditure incurred on manuring. When coconuts under

covers are manured it would be advisable, where the application is made between the rows of palms, to plough or turn the green manure in along with the artificials. Where manuring in trenches around the palms or in trenches between the rows is adopted, the green manure should be kept a good distance away from the manured trenches for at least three months after the application. The green manure material obtained from the cleared areas should be buried in the trenches along with the artificials. If ploughing or turning in cannot be done, cattle and buffaloes can be tethered around the palms in order to eat the cover and to trample down the soil at the same time. The manure can then be applied in circular trenches or forked in circles around the trees.

In regard to the treatment of cover crops on coconut estates, the most beneficial practice would be to cut and deep fork the green material into the soil at or just before flowering. This involves a heavy expenditure and will not be practicable at the present prices ruling for coconut. Ploughing in, if the cover is not too thick, is the next best procedure to adopt. Disc-harrowing as a preliminary to ploughing is also useful. If the cover is too thick it would be advisable to let cattle or buffaloes lightly graze over the area before the ploughing. The latter will doubtless utilise some of the nitrogen and minerals of the green cover for their own purposes, but a fair proportion of these fertilising ingredients will be returned to the soil in the dung. Keeping cover crops low by means of cattle is a wise practice, especially if such crops cannot be frequently turned into the soil, as the losses of nuts are minimised and snakes will perhaps not be so numerous. The frequency of forking in covers will depend entirely on the growth of the cover. Once a cover is well established it should be turned in about every other year. Alternate rows of cover, if convenient, may be treated every year.

THE PRACTICE OF GREEN MANURING AND CHOICE OF CROPS

Now that the advantages of green manuring coconuts have been indicated and some practical considerations have been dealt with, the question of suitable green manure crops will be considered in detail. Many varieties have been found useful for new clearings and mature palms. Mention will be made of only a few. It is not proposed to deal in detail with such considerations as seed rate, method of sowing or green manures suitable for a particular district. These are matters essentially for the man on the spot to discover by experiment or enquiry.

The practice of growing green manures under coconuts and oil palms is popular in the Dutch East Indies, where it is doubtless to some extent responsible for the high yields of coconuts obtained. Most of the varieties now grown in coconut and rubber-producing countries were first experimented with, and grown on a large scale, in the Dutch East Indies.[3] In the Philippines cover crops are grown on every progressive estate.[2] The green manures found most suitable are certain varieties of the lima been (*Phaseolus lunatus*). This bean is a long-lived perennial of exceedingly vigorous growth which has been reported to be useful in exterminating illuk (*Imperata arundinacea*). It dies down in prolonged dry weather, but comes up again with the rains. Unlike those of most green manure plants, its leaves cannot be used as fodder owing to the prussic acid they contain. Other plants found useful for coconuts in the Philippines are *Tephrosia candida* (Boga medeloa) and *Tephrosia vogelii*. On the poor sandy coast soils of Porto Rico, species of *Mucuna* have been very successful. *Mucuna* grows very quickly and thick, and quantities of green material (up to 6 tons per acre) are obtained. The leaves are rich in nitrogen and can be used as fodder.

Many varieties of green manure have been found suitable for coconuts in Malaya[1, 8]. Among these are *Centrosema pubescens*, *Calopogonium Mucunoides*, *Dolichos Hosei* (*Vigna*), *Centrosema plumieri*, *Pueraria phaseoloides*, besides bush varieties like *Tephrosia candida* (boga), *Tephrosia vogelii*, and *Crotalaria* spp. In India *Vigna catiang* (cowpeas) and *Dolichos uniflorus* (horse gram) are grown successfully, both as catch-crops and green manure crops[9].

In Ceylon green manuring of coconuts was undertaken as early as 1905 at the Experiment Station, Peradeniya[10]. The crops tried were cowpeas, groundnut, soy bean, *Crotalaria* spp. and boga. Cowpeas gave very good results, and so did boga and *Crotalaria*. Soy beans were not a success, perhaps due to the deficiency in the soil of the specific bacteria associated with this crop. It has been found in America that inoculation of soy beans is always necessary before the crop can be introduced into new areas. Recent trials with soy bean at Peradeniya have proved successful on areas which had grown legumes previously. Groundnut (*Arachis hypogea*) is useful as a green manure owing to its rapid growth provided it is turned in when young. It is not to be recommended as a catch-crop owing to its attraction to rats, which attack the coconuts

In young coconut plantations where the rainfall conditions are satisfactory, the growth of a cover crop is very advantageous. The bush varieties, e.g., boga, are not entirely suitable as they are inclined to become too dense and to compete with the young coconut plants unless they are grown in rows not more than 6 feet wide between the palms and are regularly lopped. The practice of growing shrubby green manures like boga or even tree green manures like *Gliricidia maculata* round very young palms is not to be recommended unless they are frequently lopped and kept low. In regard to all cover plants in young coconuts, it has to be emphasised that they must never be allowed to climb over the young palms; if they do, the latter will suffer a setback. The following will be found useful and can be recommended for young coconut areas in Ceylon: *Calopogonium mucunoides* grows well on most soils but requires good drainage. It has a tendency to climb. During periods of prolonged drought it may die out, but with the advent of the rains a fresh cover is obtained. It is best sown in rows 3 to 5 feet apart and requires weeding in its early stages. A good cover about 2 feet thick can be obtained in about four months which will die out in twelve to eighteen months. It can also be grown under old coconuts which do not give much shade, but it does not thrive so well as in the open. *Mucuna* spp., after they have formed a good cover in new clearings, should be ploughed in and followed by a more permanent cover, such as *Centrosema pubescens*, a twining creeper requiring a fairly good soil. It is rather slow in growth but forms an excellent cover in about five or six months; difficulty may be experienced at first in establishing it. If it is grown after a crop like *Mucuna* has been ploughed in, its growth will be quicker. It stands drought admirably. It does not thrive under heavy shade, but it grows well under the light shade of coconuts. *Dolichos Hosei* (commonly known as *vigna*) is more suitable for heavy shade, but does well in young clearings. The disadvantages with *vigna* are that it is rather difficult to establish on eroded hilly land, needs constant weeding, and dies down during drought. *Pueraria phaseoloides* (*javanica*) is a strong twining cover and is useful for young clearings, but it must be kept away from the young palms. It dies down in drought. It is better suited for heavy land than for sandy soils. *Centrosema plumieri*, *Dolichos lab lab*, *Dolichos biflorus* (horse gram) have also been recommended as green manures for young coconuts. *Vigna catiang*, *Vigna sinensis* (cowpeas) are suitable for both young plantations and old coconuts. The cowpea is a quick-growing annual which forms an excellent

cover in three to five months. It thrives on the poorest land and stands drought well. It is, therefore, very suitable for Ceylon coconut lands. It has been successfully used at Peradeniya as a green manure for coconuts and also in the Kurûnegala district. *Soja max* or *Glycine hispida* (soy bean), where it could be established would be suitable for young clearings as well as old coconuts. There are more than 400 varieties of this bean in existence. It is a herbaceous annual of erect growth, varying in height according to the species. It is particularly resistant to drought and will thrive on most soils except the very poor ones. Inoculation is often necessary when this crop is grown for the first time. It can be treated both as a catch-crop and a green manure crop.

Of the bush varieties of green manures *Tephrosia* spp. and *Crotalaria* spp. are most suitable for coconuts. *Clitoria cajanifolia* is also a suitable hedge plant. Of the former, *Tephrosia candida* (Boga medeloa) is perhaps the best for Ceylon conditions; hence its popularity as a green manure for coconuts. If the land is rich boga will, unless lopped, grow too tall and affect the young coconuts adversely. It should be sown in rows whenever possible. On hilly land boga should be grown in contour hedges across the slope. On poor and badly-drained soils, on which it is difficult to establish the crop, the following methods will be found useful: (1) a drain is cut and the soil heaped in mounds over husks. The seed is then sown on the mounds, a little artificial or cattle manure being added if necessary. It can also be grown on the mounds of contour terraces of coconuts; (2) cattle or buffalo manure is forked in lines between the rows before sowing the seed, the lines being previously limed if necessary. Boga gives a very heavy yield of loppings rich in nitrogen and organic matter and also in minerals because it is so deep rooted. It stands lopping well, and, like all shrubby green manures, it must be cut before the drought sets in, towards the end of the rains. It is preferable to fork the loppings into the soil if a sufficient interval of time between the turning in and the onset of the drought is anticipated. In case a sufficiently early forking is not possible, the bushes should be lopped at the beginning of the dry period and the loppings left as a mulch on the surface. In this case, the soil moisture must be conserved even at the risk of incurring appreciable losses of nitrogen. The leafy portions and the less woody material should subsequently be forked under the soil at manuring time in the manure trenches. When shrubby green manures are cut at other periods the cutting

should be done just before or at flowering. The disadvantages of shrubby green manures are the difficulty of supervising labour and of gathering the crop. Other varieties of shrubby green manures suitable for coconuts young and old are *Tephrosia vogelii*, *Cajanus indicus* (dhal), *Crotalaria striata*, *Crotalaria usaramoensis*, and *Crotalaria anagyroides*. The latter are quick growers and give large amounts of organic matter. They need frequent lopping but die off comparatively soon.

Green Manures for Old Coconuts.—The shrubby green manures have been dealt with. Of cover crops, *Centrosema pubescens*, *Centrosema plumieri*, *Dolichos Hosei*, *Pueraria phaseoloides*, *Phaseolus lunatus*, *Vigna catiang* (cowpea), *Arachis hypogea* (groundnut), *Mucuna* spp. will grow successfully if the shade is not too heavy. *Calopogonium mucunoides* is suitable if the shade is light. *Desmodium polycarpum* has been found to be a very good green manure for coconuts in the Kurunegala district. Some estates grow *Gliricidia maculata* and dadap (*Erythrina lithosperma*) between the rows of old coconuts for green manuring. While these trees may be useful in districts with good annual precipitations, they are not suitable for dry coconut districts. They are inclined to interfere with the cultivation operations of the main crop and to compete with the coconut roots for the phosphoric acid and potash of the soil. Especially on poor soils *Mikania scandens* can be left where it grows if it cannot be replaced by a green manure crop. It must, however, be ploughed in before the drought sets in. It is a non-leguminous twining weed common on estates and is useful for suppressing other weeds, e.g., illuk. It has been found useful in Malaya[1] and the Philippines [2] as a cover crop for coconuts. In general it may be stated that any leguminous plant growing on a coconut plantation should be encouraged and, if indigenous legumes grow well in the neighbourhood, attempts should be made to introduce them on the estate. In the case of non-leguminous plants which grow well outside estates, e.g., wild sunflower, it would be advantageous to lop them before they have flowered and to use the cut material for green manuring coconuts.

SUMMARY

In the preceding pages the benefits to be derived from green manuring coconuts in Ceylon are pointed out, the varieties of green manures suitable for the different soil and climatic conditions under which coconuts are grown in Ceylon have been indicated, and their treatment, especially before periods of

drought, detailed. No statistical data are available to demonstrate the effects of green manures on crop yields and the increased profits derived by the adoption of the practice, but it is acknowledged by all coconut planters who have used green manures for some time on their estates that they are distinctly beneficial both to crop and soil. Green manuring has been adopted in progressive coconut-growing countries like the Dutch East Indies and the Philippines. The wider adoption of the practice in Ceylon should eventually result in increased yields of better quality, and in a permanent improvement of the condition of coconut estates.

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SECTION V

GREEN MANURING OF PADDY

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THE application of green leaves and of green herbaceous plants to paddy fields has been practised in certain districts in Ceylon for many years but the number of acres annually manured in this manner is small. Definite green manure crops like *Crotalaria juncea* are not grown on the paddy fields in readiness for a succeeding crop of paddy; only the green leaves of trees and the herbaceous plants found near the fields are used. Many varieties of plants are utilised, including *keppitiya* (*Croton lacciferus*), *pila* (*Tephrosia purpurea*) and *peni tora* (*Cassia occidentalis*). Among the trees whose leaves are used are tamarind (*Tamarindus indica*), margosa (*Azadirachta indica*), kaduru (*Cerbera adollam*), palmyra (*Borassus flabellifer*), dadap (*Erythrina lithosperma*), *Gliricidia maculata*, and *telkekuna* (*Aleurites triloba*). The list is by no means complete and any form of green material may be used. The wild sunflower (*Tithonia diversifolia*) which grows luxuriantly and is found wild in the mid-country makes an excellent green manure and its use is thought to be extending. The green material is applied either before the first or second ploughing and generally in relatively small amounts.

The effect of applying green manures to paddy varies according to the different conditions under which the crop is grown in Ceylon. It may be said to be invariably beneficial although where a loose soil overlies a porous subsoil the addition of large amounts of green matter may militate against the formation of the good puddled condition of the soil necessary to retain in the field the irrigation water. Such conditions will rarely be found. Generally the effect of green manuring will depend upon the amount of weed growth present on the paddy field prior to the preliminary cultivation and this in turn depends upon the water supply (either direct or indirect) and largely on the length of time the land is fallow between two crops. This period may vary from less than a month to as much as eight months. Where water is available for a short period and for

one monsoon only (which frequently happens in the North-Central Province) one three-months', or at the most four-months' crop is all the land will carry for the whole year. During the seven or eight months' fallow there is generally sufficient rain to produce a vigorous weed growth. The application here of additional green material brought from outside will not produce the same effect as in districts where the weed growth is much less or where it may be entirely absent. At Peradeniya, for example, the *maha* crop is on the ground for about 200 days and the *yala* crop for 120-130 days. Preparation of the fields takes up the remaining time and at ploughing only the paddy stubble and the few weeds which have survived among the paddy plants are incorporated in the soil. Experience has shown that under these conditions (if both crops are grown during the year) the yield of the *yala* crop is very small and that the fertility of the fields can only be maintained by manuring. The villagers frequently forego the *yala* crop in order to ensure a good yield for *maha*. Under these conditions the effect of applying green material is large.

The principles and advantages of green manuring under ordinary conditions and under the anaerobic conditions in which swamp paddy is cultivated have been dealt with in Section I. Any but practical considerations will be mentioned here only briefly.

The effect of applying green material to paddy is normally to increase the yield. This is due to increasing the available nitrogen in the soil and also, it is thought, to supplying carbon dioxide to the algal film found on all paddy fields. The decomposition of the organic material may also have other effects on the chemical and physical condition of the soil and on the soil micro-organisms.

Under anaerobic conditions the decomposition of green material produces, among other things, ammonia and carbon dioxide. It has been shown by Kelly [1] and other workers that swamp paddy takes up its nitrogen mainly in the form of ammonia. The anaerobic decomposition of green material, then, directly increases the supply of that form of nitrogen useful to the paddy plant. The other effect of the decomposition of organic matter under anaerobic conditions which will be dealt with here is that due to the production of carbon dioxide.

It is stated by Brizi [2] that the roots of rice are not of the true aquatic type and he has shown that oxygen is essential to their growth. The algae which are found as a film on the surface of paddy fields (Esmarch [3, 4] has pointed out that algae are

found in the lower layers as well as in the surface soil) liberate oxygen and require for their existence carbon dioxide. The oxygen which is liberated is believed to be carried to the roots of the paddy plants dissolved in the irrigation water (Harrison and Aiyar, [5]). Brizi was the first to point out the significance of algae in the aeration of the higher plants and his contention is supported by Harrison and Aiyar who conclude that the surface film of algae is the chief agency in the aeration of the roots of rice. It will be seen, therefore, that the rôle of green manures is a dual one: they supply for the paddy plant nitrogen in the assimilable form of ammonia and carbon dioxide for the algae which liberate the oxygen necessary for root growth under the anaerobic conditions of paddy fields.

The necessity of obtaining experimental evidence as to the effect of the green manures on yield has been recognized and a preliminary experiment was carried out at Anuradhapura in 1926. There a green manure (*Crotalaria juncea*) grown *in situ* on the paddy fields resulted in a 35 per cent increase of yield in the following crop. The experiment which has already been described (Lord [6]) was not capable of valid statistical examination and moreover the control plots were ploughed later than the treated plots. The experiment, however, pointed out the necessity for obtaining information as to the effect of ploughing in green material at different times before sowing or transplanting the main crop and accordingly an experiment was started at Peradeniya in 1927. This experiment was laid down in collaboration with the Agricultural Chemist in order that the nitrogen changes in the soil could be studied. The treatments consisted of green manures ploughed in 'early' (seven weeks before sowing) and 'late' (one week before sowing), the normal weed growth ploughed in 'early' and 'late' and control plots. The five treatments were replicated four times in randomized blocks and *Crotalaria juncea* was sown on the green manure plots to supply the green material. This growing of the manures *in situ* was not satisfactory owing to the unequal growth on the different plots. Unfortunately heavy rain at harvest time spoiled yield records. The nitrogen changes which took place were extremely interesting and have been already published by Joachim and Kandiah [7] who included these results in a comprehensive field and laboratory study of the question. Essentially it was found that after ploughing in both weeds and green manures early there was an appreciable increase in the amount of ammonia present in the soil with but little increase of nitrate nitrogen. After puddling there was a sudden decrease in ammonia content but both plots remained above the level of the controls. The green manure

and weed plots ploughed in late reached their maximum ammonification during the time the paddy was in active need of ammonia. Both the late plots contained more ammonia than the early plots and the green manure late more than the weeds late. Table I taken from Joachim and Kandiah [7] shows the actual figures.

Table I

Green manure experiment (a), nitrogen determinations.

Upper figures=Mgms of nitrogen as ammonia in 100 gms. of soil at 100° C.
Lower figures=Mgms. of nitrogen as nitrate in 100 gms. of soil at 100° C.

	Before puddling				After puddling							
Time of sampling in weeks.	2	4	6	7	1	3	5	7	9	11	13	17
Control	1·5	2·1	3·0	3·23	1·22	1·73	1·31	1·05	·91	·88	·73	·27
	·55	*·96*	*·75*		*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*
Green-manure *(late)*					2·69	4·79	4·30	1·87	1·69	1·30	·87	·96
					nil	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*
Green-manure *(early)*	3·4	3·7	5·2	5·8	1·85	2·13	2·13	1·36	1·16	1·05	·83	·63
	·37	*·70*	*·78*	–	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*
Weeds *(late)*					2·14	3·06	2·50	1·41	1·42	1·37	1·25	·70
					nil	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*
Weeds *(early)*	1·4	1·6	2·7	3·0	2·02	2·36	1·89	1·27	1·08	1·04	·63	·44
	·45	*·55*	*·45*	–	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*	*nil*

The formation of ammonia prior to puddling is probably unusual and due to the plots being water-logged. Normally, as Joachim and Kandiah, have shown, the decomposition of green material prior to puddling results in the formation of nitrates. Nitrates are not used by the paddy plants and after puddling (that is under anaerobic conditions) are reduced to nitrites which may be definitely harmful to the plant. Laboratory investigations have shown that it is useless to incorporate the green material in the soil under aerobic conditions unless just prior to flooding the soil.

A similar experiment, slightly modified, was laid down at Peradeniya for the *maha* crop of 1928-29, again with the collaboration of the Agricultural Chemist. In order to ensure that the green manure plots received similar quantities of green material it was decided not to grow the manure *in situ* but to use wild sunflower brought in from outside. The application per acre was 5 tons of the green unwilted material. Green manure ploughed in early and late (respectively five weeks and one

week before transplanting) was tested against control plots. There were four replications in randomized blocks and in each 1/80 acre plot an inner area of 1/100 acre was harvested to eliminate border effect.

The results of the experiment will be found in table II.

Table II

Green manure experiment (b), yields of grain

Treatment	Calculated yield per acre mean of 4 plots of 1/100 acre lb.	bus.	Control = 100	Value of increase over control @ Rs. 2-50 per bushel
Control	2482	59	100·0	—
5 tons green manure *(early)*	3318	69	116·7	Rs. 25-00
5 tons green manure *(late)*	3847	80	135·3	Rs. 52-50

The z test is satisfactory and the standard error of the difference between means is 5 per cent. The increased yields of both the treated plots are significant and green manure *late* has beaten green manure *early*. It will be noticed that this application of a five-ton dressing of green material has had a definite effect on land whose fertility is high as judged by the mean yield of the control plot which was 2,482 lb. per acre.

The nitrogen fluctuations in the plots are interesting and will be found in table III and fig. I. The table and figure have been taken from Joachim and Kandiah [7] with the permission of the authors.

Table III

Green manure experiment (b), nitrogen determinations

Mgms. of ammonia in 100 gms. of soil at 100° C.

Before puddling				After puddling									
Time of sampling. In weeks	At start	1	3	½	2	4	6	8	11	15	Nitrogen added as green manure in lb. per acre	Period of maximum ammonification in weeks	Maximum percentage ammonified
Control	1·40	1·26	1·25	1·40	1·60	1·91	1·44	1·44	1·18	1·10	—	2-4	—
Green-Manure *(early)*	1·44	2·39	2·17	1·81	2·48	2·06	1·80	1·91	1·52	1·65	65·5	2-4	24·9
Green-Manure *(late)*	1·47	1·25	1·15	2·32	3·49	3·45	3·27	2·94	1·84	1·77	65·5	2-4	53·4

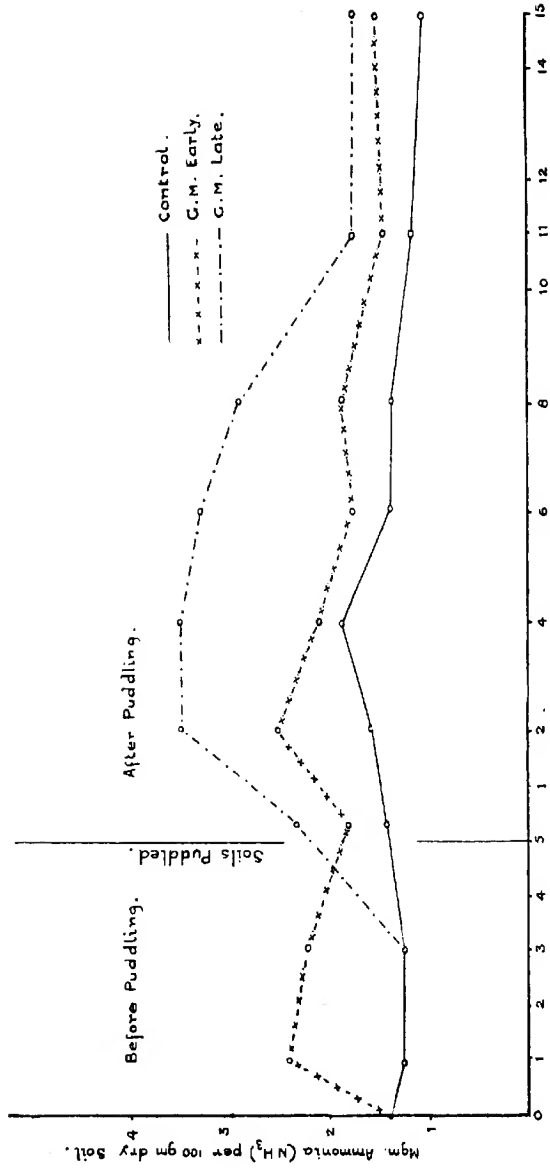

Figure I. Showing the decomposition of green manures under anaerobic conditions in the field.

Nitrate nitrogen was not found at any stage during the experiment and it was absent before puddling—the time nitrate can normally be expected—almost certainly owing to the plots being somewhat water-logged during that period. Even with soil in this condition the gain in burying the green material late, that is just before puddling, is clearly shown both by the yield figures and by the analyses.

It has been stated in India that the anaerobic decomposition of green manures gives rise to toxic products which may effect the germination of the paddy seeds. Pot experiments at Peradeniya have shown that pudding in the green material even one day before sowing has had no effect on germination. To be on the safe side, however, it is recommended that green manures should be incorporated in the soil one or two weeks before sowing or transplanting.

It will be noticed that a five-ton dressing of wild sunflower supplies a relatively large amount of nitrogen, roughly as much as is contained in 3 cwt. of sulphate of ammonia. It is quite possible that a one or two-ton dressing may be the economic or practical limit and it is also exceedingly probable that the addition of some form of phosphate to the green material will be advantageous. In many places it will be impossible to procure sufficient green material to supply a five-ton dressing per acre so the effect of a one-ton dressing is now being studied at Peradeniya. An experiment has also been devised to test the relative efficacy of green manures and sulphate of ammonia in order to determine if possible the actual value of the organic matter in the green material.

The cost of applying green manure has not been mentioned as it varies so greatly according to the ease with which it can be cut and the distance it has to be transported. Many cultivators, too, will be willing to cut green material in their spare time. It is impossible to arrive at any definite cost, although the value may be based on the amount of nitrogen the material contains. The possibility and economy of growing green manure *in situ* will have to be determined by local experience and conditions. In some districts there is insufficient time, in others insufficient water and probably in all insufficient inclination. The practical difficulties are great. Where a paddy crop is not sown cattle graze the paddy fields at will and enclosures after a crop has been harvested are unknown. There is little doubt that *Crotalaria juncea* will do well on drier fields but at Peradeniya on the wetter fields the following have been tried with little success:

Crotalaria juncea, *C. anagyroides*, *C. usaramoensis*, *Sesbania cannabina*, *Desmodium gyroides*, *Mucuna* sp., *Tithonia diversifolia* and *Vigna sinensis*.

RECOMMENDATIONS

In the present state of our knowledge of paddy cultivation the following practical recommendations may be made:

1. Green manure can confidently be applied to all normal soils except perhaps those whose fertility is well above the average.

2. One or two tons of green material per acre is a suitable dressing although smaller applications should not be disdained.

3. The green material should be applied as late as possible before sowing or transplanting, say from one to two weeks previously, and after ploughing in the soil should be kept flooded or very moist.

4. With large dressings a hundredweight of superphosphate and with small dressings a half to one hundredweight of some ammonium phosphate per acre may be recommended.

5. Where weed growth is poor application of inorganic manures should invariably be accompanied by at least a small dressing of green manure.

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SECTION VI

FUNGUS DISEASES AND GREEN MANURING

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A CONSIDERATION of fungus diseases and green manuring falls roughly into two main heads, firstly, of green manure crops and their relation to diseases of the main crop plants and, secondly, of diseases of the green manure crops themselves. It must be borne in mind that, provided that diseases of green manure plants are not of a severity sufficient to prevent them functioning as such and provided that such diseases are not passed on to the main crop plants for the benefit of which the green manure plants are grown, the diseases of green manure plants are of relatively little importance. It is possible that the perusal of a list of diseases of certain groups of plants might give the impression that such plants are often and severely attacked by disease and that their presence may constitute a danger. It would be as well, therefore, to point out at the beginning of this section that the value of green manuring is so great as to warrant amply the adoption of measures to control serious diseases of the green manure plants and to prevent the main crop plants from suffering unduly from disease as a consequence of their presence. Such measures must be, of necessity, simple and inexpensive. If one form of green manure plant is found to be unsatisfactory on account of disease it is often possible to replace it with another plant equally satisfactory as a green manure and less susceptible to the disease in question.

It is proposed to consider chiefly green manures and their relation to disease in the main crop plants in which they are grown and to give brief notes only on the diseases of the green manures themselves.

1. GREEN MANURES AND THEIR RELATION TO DISEASE OF ECONOMIC CROPS

Root Disease.—All woody plants are susceptible to root disease and green manure trees and shade trees are no exception to this rule. The extent of attack and the rapidity of death after attack vary in different plants and under different conditions. Generally speaking, root

diseases flourish in damp situations and in good soils and kill with greater rapidity trees with soft, easily penetrated roots. The common fungi associated with root disease such as *Fomes lignosus*, *Fomes lamaœnsis*, *Poria hypolateritia* and *Rhizoctonia bataticola* are known to occur on a great variety of host plants although there seems to be a certain preferential association of certain plants and certain root diseases, for instance, *Hevea* and *Fomes lignosus*, tea and *Poria hypolateritia*, and cacao and *Fomes lamaœnsis*. This may not be so much a question of individual susceptibilty as of conditions prevailing which are most favourable for the development and parasitism of individual fungi. There is no indication of unusual susceptibility to root disease in any of the green manure and shade trees commonly grown in Ceylon while, as far as is known, none of them are immune.

It is, therefore, obvious that, while they are growing, green manure and shade trees do not constitute a danger, as far as root disease is concerned, to the crop plants in which they are grown. It has been the practice, however, to cut out such trees periodically for firewood, or when the trees become inconveniently large; if the stumps and roots are left in the ground then the root disease question assumes a greater importance. Petch[1] has pointed this out and says:

> "In old tea, the chief source of root disease lies in the stumps of shade trees which have been felled. *Grevillea robusta* is a notorious offender in this respect, and its stumps very frequently give rise to *Ustulina*, or, more rarely, to Brown Root disease. When Grevilleas have to be got rid of, their stumps should be dug out. Jak (*Artocarpus integrifolia* and Dadap (*Erythrina lithosperma*) have been found to serve as a starting-point for *Fomes lignosus*. *Albizzia moluccana* is one of the most difficult shade trees to deal with in connection with root diseases, and one is inclined to recommend that it should never be planted through tea. Owing to its rapid growth, it usually gets out of hand in a few years, and, in certain of the low-country districts of Ceylon, trees with trunks 4 feet in diameter were formerly not uncommon in tea. When cut down, its stumps very generally afford a place of origin for *Ustulina*, *Diplodia*, and *Poria*, and large numbers of bushes are killed out round them. With regard to these common shade, or green manure, trees of tea, it might almost be said that from their stumps root disease is the rule rather than the exception."

The same applies to stumps of green manures or shade trees when left in the soil among other woody crops, such as cacao or rubber. The reason why deaths from root disease should occur round stumps is not quite clear. Butler[2] in his report on diseases of tea in Nyasaland states:

> "As the stumps decay, patches of dying tea are noticed around them, and these may continue to expand for a considerable period unless arrested. I have not seen an adequate explanation of this phenomenon, through the immediate cause of the death of the bushes—the action of certain parasitic fungi which attack the root—is well known. How it is that these fungi require the presence of decaying wood, usually in large masses, to start them into activity is obscure."

A possible explanation is that the air-borne spores of the root disease fungi find in the decaying stumps conditions most favourable for their germination and development.

Danger from root disease caused in this way can be avoided by removing the stumps when felling green manure trees. When the trees have been allowed to grow to a considerable size this is a difficult and costly operation. The modern tendency in estate practice is to remove shade trees before they become large enough to be troublesome. This is particularly applicable to albizzias and dadaps at low and mid-country elevations. Sometimes, when trees, e.g., grevilleas, are grown for firewood in addition, it is more practicable to leave them longer and to exert care in removal. In this connection it is perhaps worthy of note that certain 'tree-killers' are on the market, the proprietors of which claim that the roots of trees killed by them are impregnated with poison and in consequence do not harbour parasitic fungi. A 'tree-killer' is being tested now; so far results show that trees to which the poison is applied die more quickly than those which are ringed in the usual way, but a considerable period of time must elapse before any useful data can be obtained on the effect on the roots. If the claims are substantiated the danger of root disease originating from stumps and roots left in the ground will be lessened by using the 'tree-killer'.

In addition to the green manure and shade trees there are erect covers such as *Tephrosia candida* and *Crotalaria* spp. which become woody with age and, when woody, may be attacked by the common root diseases. Green manure plants of this type are lopped periodically and after about two years branches may die back and act to a lesser degree in a manner similar to the

stumps referred to above. *Tephrosia candida*, if left too long, is susceptible to a root disease caused by *Irpex subvinosus* which from this source has been known to pass to and attack tea. Erect green manure plants should therefore be removed and replanted periodically. The stumps must be removed completely—an operation not very difficult if two years is the limit of time they are allowed to grow.

Green manures have yet another bearing on the incidence of root disease in woody crop plants. Murray [3] pointed out that a thick cover of vigna (*Dolichos Hosei*) produces conditions favourable for the rapid spread of *Fomes lignosus* in rubber. Although vigna is not attacked by the fungus, the moist conditions prevailing under the cover produced by the plant favour the activity of the fungus, while the older runners of the plant act as convenient footholds for the strands of mycelium which pass along them. Similar conditions occur when other cover crops are grown, and cover plants when allowed to grow up the base of trees may conceal fructifications or decaying tissue and thus aid the spread of root disease by preventing prompt treatment. A sound recommendation is that the cover plants should be cleared away to a distance of about 3 feet from the base of the trees. In addition to this, where root disease occurs, the area containing affected and suspected trees should be completely cleared and kept clean weeded; isolation trenches should be kept clear of cover plants.

There remains a consideration of green manures and their relation to root disease in herbaceous plants. It is unusual for green manure plants to be grown simultaneously with herbaceous crops, but it is a common practice to turn in leguminous or other green manure plants prior to growing the main crop. Gadd and Bertus [4] noted the occurrence of *Rhizoctonia Solani* (*Corticium vagum*) on vigna and other cover plants and showed by experiment that the fungus was capable of attacking a very large range of plants in the seedling stage. Weir [5] drew attention to diseases of cover crops grown under rubber in Malaya caused by *Rhizoctonia Solani*, *Sclerotium Rolfsii* and *Pythium* sp. The two former are sclerotial fungi and produce resting bodies or sclerotia which are capable of germinating in soil after long periods. The presence of these fungi on the green manure plants and the subsequent infection of the soil when the green manure plants are mulched into the soil might lead to heavy losses of main crop plants soon after germination. It should be pointed out that not only do these fungi attack and kill herbaceous plants such as tobacco, brinjal, and chilli, but they are

parasitic on young seedlings of tea and rubber and other plants which subsequently become woody. The need for eradication of diseases of the cover crops as soon as they appear and the need for care in avoiding infection of the soil by this type of fungus is therefore of importance. The question of control will be considered later in the notes on the diseases of green manure plants.

Although certain parasitic fungi may be introduced into the soil in green manuring this infection can be avoided with a little care. It is possible that with certain diseases actual benefit may be derived from green manuring in the suppression of disease. Millard and Taylor [6] have shown that the prevalence of potato scab (*Actinomyces scabies*) is decreased by green manuring. They suggested that green manuring may encourage the growth of saprophytic organisms with the result that parasitic organisms are suppressed. It will not be out of place to state again that the benefits derived from green manuring are such as to justify amply the adoption of a little care in controlling any root diseases that might be encouraged by, or introduced in, the process.

Stem diseases.—There are two stem diseases of woody green manure plants which also attack main crop plants in Ceylon. Pink disease (*Corticium salmonicolor*) has been recorded on *Gliricidia maculata*, *Crotalaria* spp. and *Desmodium heterocarpum*, while the alga, *Cephaleuros parasiticus*, has been found to attack boga (*Tephrosia candida*). The former of these diseases has been known on tea and rubber although on neither is it a serious disease in Ceylon, while red rust is common on tea and has occurred on cinnamon, coffee, and rubber. There is no indication that green manure plants are more susceptible to these diseases than the main crop plants on which they have been known to occur and their eradication from the green manure plants is relatively simple.

It is possible that the presence of cover crops may affect the incidence of certain stem diseases of the trees under which they are grown by increasing the humidity of the atmosphere. There is no record of the increase of such diseases as bark rot or stem canker of rubber where cover crops are grown, but diseases of this type are favoured by humid conditions and it is conceivable that a thick cover of vigna or some similar green manure plant might, by increasing the humidity, tend to increase the incidence of these diseases. This is, however, unlikely ever to become important in Ceylon where effective preventive application of disinfectants is the common practice.

Leaf disease.—It is in connection with leaf disease that the planting of certain green manure trees affects intimately the incidence of disease in the crop plant. *Cercosporella Theae* is considered to be the most serious disease of tea grown in a wet climate at high elevations. The incidence of this disease is directly correlated with the growth of certain shade trees, particularly of *Acacia decurrens*, under such conditions. Petch (*loc. cit.*) showed that the disease first attacks acacias and spreads from them to the tea. He pointed out that, usually, the disease occurs on tea interplanted with *Acacia decurrens*, but that it also attacks *Acacia dealbata*, *Acacia melanoxylon*, karri (*Eucalyptus diversicolor*), and red gum (*Eucalyptus robusta*). Gadd [7] extended the host range of *Cercosporella* by including *Albizzia lopantha*. Petch (*loc. cit.*) described the progress of the disease thus:

"When *Acacia decurrens* is attacked, the trees are defoliated, the leaflets and the leaf-stalk, or rachis, falling separately. The smaller branches may die back, and young plants may be killed, but, in general, the trees put out new foliage when drier weather supervenes.

"The disease is conveyed from the Acacias to the tea, either by means of its spores which are blown by the wind, or washed by the rain, on to the surrounding bushes, or by the falling leaflets of the *Acacia*. As the leaflets are small and flat, they adhere, when moist, to the leaves of the tea bush long enough to enable the fungus to grow from them to the tea leaf. It is easy to find in an affected field numerous instances in which an *Acacia* leaflet is attached to a tea leaf by a weft of mycelium in the middle of a diseased patch, and others in which a spot is beginning to form from a similarly attached leaflet. In general, it would appear that the smaller circular spots are the result of an infection by spores, while the larger patches are due to the transference of the fungus by means of the falling *Acacia* leaflets, but that is not universally the case. Naturally, when the disease is transferred by a leaflet, the mycelium is superficial on the tea leaf from the beginning of formation of the spot."

The disease occurs only in the areas of tea which are subject to conditions of high humidity and particularly in those areas where mists are prevalent. Areas of tea which are not in the 'mist zone' but which get the same amount of rainfall as those nearby but within the 'mist zone' are not affected to nearly the same extent as the latter. It is obvious, therefore, that the areas of tea in Ceylon which are subject to severe attacks of *Cercosporella* are not very great. It is unfortunate that, at the elevation at which the disease is most severe, the number of

shade and green manure trees which grow satisfactorily is extremely limited and that, of these, *Acacia* is certainly the best. Whether it is advisable to cut out the acacias in those areas in which the disease occurs is a question which must be dealt with in the light of experience on each estate. In some instances it will be found that the damage caused by the disease more than balances the benefit obtained in green manuring and shade from the acacias. From such areas the trees should be removed. The disease occurs during definite seasons and it might be possible to avoid serious infection by lopping the acacias prior to those seasons. Meanwhile, endeavours should be made to find a green manure and shade tree immune to *Cercosporella* which could replace the acacias.

There are no other leaf diseases of economic plants which have been shown to be correlated in any way with the presence of green manure plants. It should be pointed out, however, that *Centrosema pubescens* is attacked by an *Oidium* which is similar in morphological characters to that which attacks *Hevea*. It is not possible to state if it is the same species nor has the fungus been proved to be capable of attacking *Hevea*. Even if it were, it is ulikely that the presence of the fungus on the cover crop would affect the severity of attack on *Hevea* since, in those areas in which *Oidium* occurs on rubber, the fungus is usually present to such an extent on the rubber that its occurrence on the cover crop would make little difference.

2. DISEASES OF GREEN MANURE PLANTS

A large number of diseases of green manure plants have been recorded in Ceylon, but with very few exceptions, they do not constitute a limiting factor to the growth of these plants. Certain diseases, however, have proved to be troublesome and for that reason are dealt with at some length below:

Sclerotial diseases of cover crops.—The two chief organisms causing diseases under this head are *Rhizoctonia* (*Corticium*) *Solani* and *Sclerotium Rolfsii* and of these the former has proved to be much more common on estates in Ceylon. Wier (*loc. cit.*) has reported *Rhizoctonia Solani* on *Calopogonium* and vigna in Malaya, while in Ceylon it is common on vigna, cowpea and *Dunbaria Heynei*.

The effects of the two diseases are somewhat similar. Brown and roughly circular patches occur in the cover ranging in diameter from a few inches up to several yards. These patches are particularly noticeable in areas in which the cover is well grown, since affected areas are somewhat sunken below

the general level of the cover. Outbreaks occur most commonly during wet weather. The two diseases differ when examined closely and are therefore described separately.

Rhizoctonia (*Corticium*) *Solani*.—On a close examination of a patch of vigna attacked by *Rhizoctonia* (*Corticium*) *Solani* the majority of the leaves, particularly of the lower ones, may be seen to be rotting and bound together by wefts of cobweb-like mycelium which can be traced readily on most of the affected leaves and stems. Loosely attached to diseased stems and leaves near the ground are found the sclerotia or resting bodies of the fungus. In appearance sclerotia are not unlike fine gravel or small soil fragments and range in size from 0·5 to 4 mm. in diameter. Sclerotia are very resistant to adverse conditions and serve to tide the fungus over periods of drought and, being but loosely attached, they are readily dropped into the soil. By these the fungus is carried over from wet season to wet season.

The perfect (*Corticium*) stage of the fungus has been observed but rarely on vigna in Ceylon. It occurs on green stems and on the under surface of green leaves in, or adjacent to, affected areas as a white or greyish powdery layer. This layer can be removed entirely with the point of a needle and consists of a basal network of loosely woven hyphae from which spring basidia on the apex of each of which are borne four hyaline, oval, apiculate spores. It is interesting to note that the leaves on which this stage of the fungus is formed are not injured by the fungus and appear to act merely as supporting surfaces for the spore-bearing mycelium. The spores measure 7-12 by 4-6 microns.

Sclerotium Rolfsii.—*Sclerotium Rolfsii* has been recorded in Ceylon on vigna and *Crotalaria* but is common on neither. It is, however, common in tropical and sub-tropical regions and may cause serious losses of herbaceous garden and field crops. Bertus [8] has written a full account of its occurrence in Ceylon and has shown that it is capable of attacking a wide range of herbaceous plants. The growth of the fungus on infected plants is characteristic. Strands of white mycelium occur on affeced stems and these on reaching the leaves may spread into silky fan-shaped growths of hyphae. Attached lightly to the mycelium and to dead stems and leaves are found sclerotia which are at first white and then yellow-brown, spherical, smooth and shining and 1-1·5 mm. in diameter, similar in appearance to mustard seed. The functions of these sclerotia are as described above and these again are capable of remaining viable for long periods under dry conditions. No perfect or spore-bearing stage of *Sclerotium Rolfsii* has been observed.

Treatment.—The ideal control measure for all soil-inhabiting parasitic organisms is that of soil sterilisation. This, however, is impracticable under field conditions. It is essential that measures for the control of diseases of green manure plants in general should be cheap and efficacious. In Malaya, Weir (*loc. cit.*) has recommended the isolation of patches affected by these fungi by means of a trench 18 inches deep and the treatment of the enclosed area with a soil fungicide. He points out that fungi of the type under discussion do not penetrate the soil to any great depth and emphasizes the need of keeping the trenches clear.

In Ceylon, the general recommendation is the collection of all affected plants within an area, together with a border of apparently healthy plants—a border 3 feet wide all round the patch should suffice. It is important that the plants collected should be burned wihin the patch if possible and the surface soil of the patch should be scraped lightly together and heated by the fire in order to kill the sclerotia of the parasite which have fallen on it. If burning within the area is impracticable the dead plants, together with the soil scrapings, should be taken away in tins or some similar receptacles since there is otherwise a danger of dropping sclerotia and infecting other areas during the transportation to the place of destruction. Treated patches should be kept clean for a period of at least one year.

In those areas in which the burning of diseased plants *in situ* is not practicable, the recommendation made in Malaya of applying disinfectants might be adopted. The ground should be cleared as above and a liberal application (1 quart per square foot) made of a two per cent solution of formalin, a one per cent solution of blue vitriol (copper sulphate) or Jeyes' fluid at the rate of 1 ounce Jeyes' fluid to one gallon of water.

Dying back of shade and green manure trees.—From time to time numerous requests for advice have been received concerning the dying back of certain shade and green manure trees —particularly of dadaps and grevilleas. That such trouble is wide-spread was made clear by the answers to the questionnaire on green manuring recently circulated to estates in Ceylon. The diseases of dadaps and grevilleas are distinct and are discussed briefly below.

Dadap.—There are two dieases of dadap which result in dying back. One is caused by *Fusarium* sp. and has been described by the writer [9], while the other results from eelworm injury in the roots and has been described by Gadd [10].

Fusarium die-back.—The disease occurs after lopping. Green-brown or olive water-soaked blisters appear on the cortex of lopped branches and as the disease advances these may amalgamate and finally dry out to become characteristic sunken areas of dead cortex, brown in colour. The lenticels of the area affected develop pinkish-white pustules of spores of the causal fungus. The disease is most active in wet weather and occurs in the Uva district and, to a lesser extent, in other up-country districts. When grown in situations favourable for their growth, young vigorous trees are not affected seriously by the disease. Old trees, after repeated loppings, and trees in exposed situations and grown under unfavourable conditions may suffer extensively, while the time of lopping appears to influence the severity of attack.

The dadap, like certain other trees used for the same purpose, has a limited economic life since after repeated loppings it becomes increasingly susceptible to disease. The common estate practice is to replant when trees become unthrifty. The age at which trees should be removed and replanted varies in different districts but usually lies between ten and fifteen years. The replanting of dadaps as soon as they begin to show symptoms of degeneration and increasing susceptibility to disease, and lopping only at times when the trees are at the beginning of a period of vigorous growth, i.e., when the sap is running, will tend to minimise the possibility of extensive *Fusarium* die-back.

Eelworm disease.—Eelworm disease of dadap is common in certain districts in Ceylon, particularly Maskeliya, at an elevation above 4,000 feet. Affected trees show poor growth, the leaves being undersized, pale in colour and few in number. Lower leaves fall off prematurely and in advanced cases branches die back, the trees having, in consequence, a thin and unthrifty appearance. The most typical symptom is the crowded state of the leaf scars on the shoots of affected trees, which is the result of suppression of normal growth followed by defoliation. An examination of the roots of such trees shows galls typical of nematode infestation in both large and small roots. The galls vary in size and are easily distinguishable from the nodules caused by nitrogen-fixing bacteria which are more or less spherical, easily detached and present only on the smaller roots. Eelworm galls are enlargements of the roots themselves and when cut open the female nematodes may be seen as glistening white or pearly white, rounded, pear-shaped bodies about half

the size of a pin's head. The general effect of the root infestation is the lowering of the vitality of the trees and the consequent increase in susceptibility to fungus attack and to unfavourable conditions.

The eelworm is known as a serious parasite of tea seedlings and has been known to attack roots of old tea, although not commonly. Dadaps affected by eelworms should therefore be treated. No satisfactory method other than some form of soil sterilisation has been evolved for the control of eelworm. In areas in which eelworm disease occurs dadaps should be removed as completely as possible and the roots burned and some other form of shade or green manure tree established.

Grevillea.—The elevation to which grevilleas can be grown in Ceylon is limited and as the upper limit is approached a die-back is common on trees of over ten years of age. That this die-back is affected by adverse conditions is shown where exposed trees on poor soil exhibit the die-back symptoms, while older trees in the same or adjoining fields, grown under more favourable conditions, do not exhibit the symptoms. Trees die from the top slowly and a close examination of the portions dying back and of the roots fails to disclose any parasitic fungus. As the die-back advances it may be accompanied by a gummosis, the bark cracking vertically and gum exuding; in extreme cases the trees die and an examination of the roots reveals the presence of the fungus, *Rhizoctonia bataticola*. How far this fungus is responsible for the die-back it is impossible to say, but it is clear that unfavourable conditions, such as high elevation, exposure and poor soil render trees over a certain age susceptible to this form of die-back. There appears to be no difficulty in re-establishing young trees in these areas and the common estate practice in Ceylon is to replant grevilleas when they first show indications of this degeneration and to use the timber of the older trees for firewood.

The die-back of mature grevilleas planted at elevations over 5,000 feet should not be confused with a superficially similar die-back caused by *Calotermes Greeni* which is referred to elsewhere.

The African or Kalutara Snail (*Achatina fulica*).—In rubber growing districts in Ceylon the African or Kalutara Snail has done extensive damage to cover crops by eating green leaves and stems. On some estates damage has been so severe as to constitute a limiting factor to the establishing and growth of such covers as vigna and the interest of the planting community has been roused. The snail is very common and, as most of the depredations take place at night, the presence of large

numbers of snails escapes notice since they hide under stones, etc., during the day. Although attention has been directed to the problem of controlling the pest no satisfactory control has so far been evolved. Short notes are given below on methods of control which have been suggested.

Predatory animals.—A number of animals eat the Kalutara snail and it has been suggested that endeavours be made to increase their numbers. A number of birds eat the young snails and the ruddy mongoose is said to feed on the snails extensively. None of these, however, feeds solely upon the snail nor is it likely that any form of protection or measures that might result in an increase in their numbers would be of material benefit, while there is always the possibility that such measures might result in overwhelming disadvantages in other directions. Hutson and Austin [11] drew attention to the possible value of the Indian glow-worm (*Lamprophorus tenebrosus*) in controlling the snail, but the experience of several years indicates that the insect breeds too slowly to effect efficient control.

Collection.—Hand collection of the snails is one of the most popular methods of control. Very large numbers can be collected but figures taken over a long period do not indicate that such collection is likely ever to result in a marked diminution of numbers and an efficient control. Collected snails are destroyed by pouring boiling water over them or by burying them in a deep pit with unslaked lime.

Use of poisons.—Poisons have been used in two ways, by spraying the cover with a poison and by applying a poison mixed with lime to rocks, etc., throughout the infected area. In the former method, the cover is sprayed with a solution of copper sulphate or with Bordeaux mixture. This appears to give satisfactory results but the expense and the necessity of repeated applications tend to render it impracticable.

The use of a poison such as the "Atlas" poison mixed with limewash and applied to the under surface of rocks and stones has been tested under estate conditions. Reports of results are somewhat contradictory; some estate superintendents have stated that this treatment is effective, while others have reviewed results unfavourably. It is difficult to estimate the number of snails killed by the treatment since the number of empty shells is the only indication of the number of snails killed and it is conceivable that a much greater number are killed in this way than the empty shells found would indicate.

General.—Until results of experiments now in progress are available, it would appear that the best method of control of the snail pest is a combination of collection and the application of Atlas-limewash to rocks and stones.

A LIST OF DISEASES OF GREEN MANURE PLANTS IN CEYLON

Shade trees.

Acacia decurrens Willd. Black wattle.

Root diseases:

Armillaria fuscipes Petch.
Fomes applanatus Pers.
Irpex subvinosus B. & Br.
Rhizoctonia bataticola (Taub.) Butl.

Stem disease:

Nectria pulcherrima B. & Br.—Canker.

Leaf disease:

Cercosporella Theae Petch.

Albizzia lopantha Benth. Cape wattle.

Root diseases:

Poria hypolateritia Berk.
Rhizoctonia bataticola (Taub.) Butl.

Leaf disease:

Cercosporella Theae Petch.

Albizzia moluccana Miq.

Root diseases:

Botryodiplodia Theobromae Pat.
Fomes lucidus (Leys.) Fr.
Poria hypolateritia Berk.
Rhizoctonia bataticola (Taub.) Butl.
Ustulina zonata Lév.

Stem disease:

Nectria pulcherrima B. and Br.—Canker.

Seedling diseases:

Eelworm disease of roots (*Caconema radicicola* (Greef) Cobb.

Rhizoctonia Solani Kühn (*Corticium Solani*)——Sore shin.

Ceratophorum Albizziae Petch.—Sore shin on leaves.

Erythrina lithosperma Bl. Dadap.

Root diseases:

Fomes lamaoensis Murr.—Brown root disease.
Fomes lignosus Klotzsch.
Poria hypobrunnea Petch.
Rhizoctonia bataticola (Taub.) Butl.
Ustulina zonata Lév.
Caconema radicicola (Greef) Cobb.—Eelworm disease.

Stem diseases:

Botryodiplodia Theobromae Pat.
Fusarium sp.—Die-back.
Phyllosticta Erythrinae Petch.

Leaf diseases:

Coleosporium Erythrinae Petch.
Phyllosticta Erythrinae Petch.
Hendersonia obesa Petch.—Leaf spot.

Eucalyptus spp.

Root Disease:

Rhizoctonia bataticola (Taub.) Butl.

Leaf diseases:

Cercosporella Theae Petch.
Pestalozzia disseminata Thuem.
Stictis emarginata Cke. & Mass.

Seedling disease:

Rhizoctonia sp.—Collar rot.

Gliricidia maculata H.B.K.

Root Diseases:

Fomes lamaoensis Murr.—Brown root disease.
Sphaerostilbe repens B. & Br.
Ustulina zonata Lév.

Stem disease:

Corticium salmonicolor B. & Br.—Pink disease

Grevillea robusta A. Cunn. Silky oak.

Root Diseases:

Botryodiplodia Theobromae Pat.
Fomes lamaoensis Murr.—Brown root disease.
Rhizoctonia bataticola (Taub.) Butl.
Ustulina zonata Lév.

Seedling disease:

Rhizoctonia bataticola (Taub.) Butl.—Collar rot.

Leucaena glauca Benth.

Root disease:

Poria hypobrunnea Petch.

Green manure plants.

Clitoria cajanifolia Benth.

Root disease:

Rhizoctonia bataticola (Taub.) Butl.

Crotalaria spp.

Root disease:

Rhizoctonia bataticola (Taub.) Butl.

Stem disease:

Sclerotium Rolfsii Sacc.

Leaf diseases:

Cercospora Crotalariae Sacc.
Colletotrichum Crotalariae Petch.
Parodiella grammodes Kze.
Phyllosticta Crotalariae Sacc.
Sphaerella Crotalariae Petch.

Tephrosia candida DC. Boga medeloa.

Root diseases:

Fomes lamaoensis Murr.—Brown root disease
Irpex subvinosus (B. & Br.) Petch.
Poria hypobrunnea Petch.
Rhizoctonia bataticola (Taub.) Butl.
Rosellinia arcuata Petch.

Cover crops.

Centrosema pubescens Benth.

Leaf disease:

Oidium sp.—Mildew.

Desmodium heterocarpum DC.

Root disease:

Rhizoctonia bataticola (Taub.) Butl.

Stem disease:

Corticium salmonicolor B. & Br.—Pink disease

Dolichos Hosei Craib (*Vigna oligosperma*)

Root, stem and leaf diseases:

Rhizoctonia Solani Kühn (*Corticium Solani*)
Sclerotium Rolfsii Sacc.

Leaf disease:

Uromyces (?) sp.—Rust.

Dunbaria Heynei W. & A.

Root and stem diseases:

Rhizoctonia Solani Kühn (*Corticium Solani*)

Vigna catiang Walp. var. *sinensis* Endl.—Cowpea.

Root and stem disease:

Rhizoctonia Solani Kühn (*Corticium Solani*)

Leaf disease:

Uromyces appendiculatus (Pers.) Link.—Rust.

The above list is by no means complete and has been compiled from the records of the Mycological Division and from Bulletin 83 [12]. The specimens examined in the course of routine advisory work may, however, be assumed to have given a fairly comprehensive list of the more serious diseases of the green manure plants in Ceylon with the exception of those only recently introduced from other countries.

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SECTION VII

INSECT PESTS AND GREEN MANURING

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IN this section it is proposed to touch briefly upon some of the more important insect pests by which green manures are liable to be attacked and to suggest certain measures of control. The term "green manures" will be used throughout to include shade trees and cover crops.

At the Agricultural Conference held at Peradeniya in March 1927, the writer [7] drew attention to the fact that the vast extension within recent years of the areas under leguminous green manure plants is being followed not only by a marked increase in the prevalence of certain insects already known to attack these plants but also by the appearance of other insects not previously recorded on them. This increase in the actual prevalence of the established green manure pests and in the number of potential pests of these plants is only to be expected when we take into consideration that many of our present insect pests of the principal cultivated crops of the Island, including green manures, are indigenous to Ceylon or to South India and have been polyphagous or general feeders on a great variety of wild host plants for very many years.

The introduction into Ceylon of most of our estate crops has provided, and will continue to provide, many of our native insects with a great variety of new and attractive food plants. Moreover, it is probable that many of these insects, while gradually transferring their attention to cultivated plants, have still retained their liking for their original wild host plants. This persistent ability of many of the insect pests of our plantation crops to live on a great variety of wild plants tends to make the eradication of these pests a practical impossibility. There is, however, some compensation in the fact that many of our local insect pests are native to this Island or to South India, namely, that many of their natural enemies, such as parasitic and predaceous insects, are also probably indigenous and we are thus

guaranteed a periodical control of many of our native insect pests by their local enemies. Since no parasitic insect can be expected to accomplish anything more effective than a partial, and therefore only periodical, control of its insect host, it follows that from time to time we are bound to suffer from more or less serious attacks on our cultivated crops, including green manure plants, by certain insects which have succeeded in breeding up rapidly during a temporary weakness in the prevalence of their natural enemies.

The following account of some of the green manure pests which have come under the observation and investigation of this Department and of the Tea Research Institute within recent years, together with brief notes on a few other newly-recorded potential pests of these crops, will be given under three main headings, indicating the nature of the damage, namely, leaf-eating pests, borers, and sucking insects. The various insects are grouped under their favourite green manure plant. The leaf-eating insects include grass-hoppers or locusts, caterpillars and beetles; a few leaf-eaters also attack the flowers and pods of their food plants. The borers usually attack the shoots, branches, and stems, but occasionally their injury may extend down into the roots; among the boring insects are included caterpillars, beetles, and termites. Sucking insects include plant bugs, aphids, scale insects, and mealy-bugs; this group of insects may attack almost all portions of the plants except perhaps the lower roots.

LEAF-EATING INSECTS

Pests of Dadap (*Erythrina* spp.).—One of the most voracious pests of dadap is the spotted locust (*Aularches miliaris*) which attacks this crop mainly in the northern portion of the Central Province, and outbreaks occur annually in some part of this area. The following brief note taken from a fuller account of this pest published by the writer [6] in 1927 summarises the main features of its life-history and indicates briefly the control measures to be adopted. The locusts attain the adult winged stage (Pl. I, Fig. 1) during July, August, and September, and after a period of wide-spread activity and voracious feeding, during which many acres of dadap may be completely stripped even to the tender bark, they mate, and egg-laying goes on during October, November, and December. The eggs are laid in masses in holes in the ground (Fig. 4) and the adult locusts of both sexes die after egg-laying is completed. The eggs hatch in about four months and the young locusts or "hoppers" (Fig. 6) come swarming out of the ground in

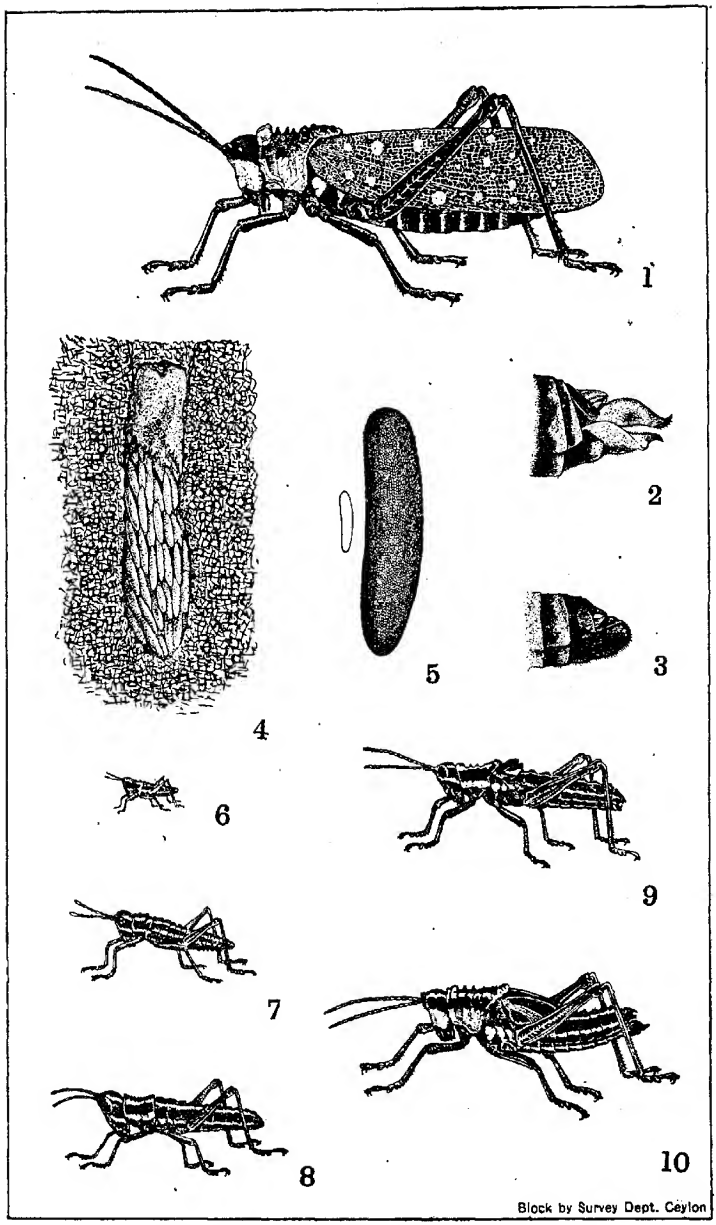

Plate I.—The Spotted Locust (*Aularches miliaris*)

Fig. 1. Full grown female.
Fig. 2. Side view of posterior portion of female.
Fig. 3. Side view of posterior portion of male.
Fig. 4. Section of soil showing egg-mass in its hole. A portion of the porous matter enclosing the eggs has been removed, but the plug of the same material is seen above the eggs.
Fig. 5. Egg × 4.
Figs. 6-10.—Five of the six stages of the nymphs or young locusts.

All figures are natural size except Fig. 5.

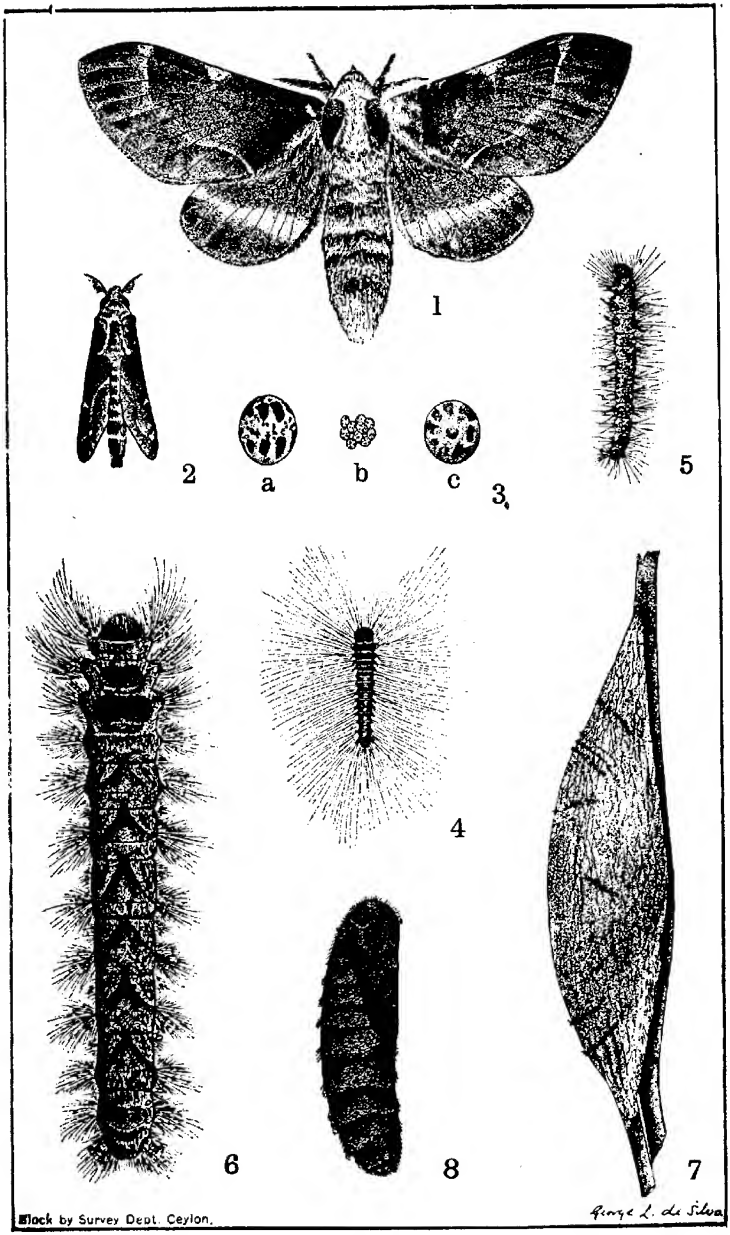

Plate II.—The Various Stages of *Taragama dorsalis*

Fig. 1. Female moth, wings spread, nat. size.
Fig. 2. Male moth, wings closed, nat. size.
Fig. 3. Eggs, *a* side view × 5, *b* group of eggs, nat. size, *c* top view × 5.
Fig. 4. First instar caterpillar × 8.
Fig. 5. Second instar caterpillar × 1½.
Fig. 6. Fifth instar or full-grown caterpillar, nat. size.
Fig. 7. Cocoon of female, nat. size.
Fig. 8. Pupa of female, removed from cocoon, nat. size.

seething masses during the following February, March, and April. For the first few days they cluster thickly on any low-growing plant and even at this early stage they can collectively strip any favourite food plant, such as dadap. They gradually scatter further afield with ever-increasing appetites, and, unless they are killed off within the first few weeks after emergence, they gradually spread from one field to another or to an adjoining estate, defoliating the dadaps in their advance. They become full-grown and get their wings in about five months, that is during July, August, and September again. Only one brood is produced during the twelve months.

Control Measures.—These include the collection and destruction of the winged locusts on their breeding grounds during October to December, the marking down and forking over the egg-laying areas during November to January and the destruction of the newly-hatched hoppers by spraying them as they emerge or cluster on low-growing vegetation during the early months of the year. A simple and effective spray is a solution of soap and water made by dissolving any good hard or soft soap in water at the rate of 1 lb. in 8 gallons for hoppers up to about two weeks old (Fig. 6) and at the rate of 1 lb. in 6 gallons for hoppers from about two to about six weeks old (Fig 7). The hoppers should be sprayed as soon as possible after emergence and while they are still crowded together on low-growing plants. It is useless attempting to spray them after they are more than six weeks old, since they are then too active and too hardy to be wet and killed by the spray.

Caterpillar Pests of Dadap.—There are several kinds of caterpillars which are known to attack the leaves of dadap from time to time, but fortunately their outbreaks are few and far between. The keen interest in insect pests now being taken on most estates usually leads to the detection and destruction of any outbreak before much damage is done; occasionally, however, acres of dadaps may be defoliated by armies of caterpillars which seem to appear almost in a night.

The largest and most destructive of the caterpillar pests of dadap are those of the two Lasiocampid moths, *Taragama dorsalis* (Pl. II, Fig. 1) and *Suana concolor*. Of these two, *Taragama* occurs more frequently on dadap than *Suana* and the following brief note from a previous article by the writer [5] may be of interest: The rather large brown-spotted eggs (Fig. 3) of *Taragama* are usually stuck in masses to the branches of dadap and other plants and hatch in about 12 days. The caterpillars are full-grown (Fig. 6) in about 5 or 6 weeks and during the last two

weeks of their development they consume vast quantities of leaf. Dadap and *Albizzia* are their favourite food plants but they may also feed to some extent on almost any of the main crops, such as tea, rubber, cacao, etc. The caterpillars attach their stoutly-woven cocoons (Fig. 7) to any convenient objects, such as the branches and stems of their food plants. The pupal stage lasts for about 2 to 3 weeks. Under field conditions the complete life cycle probably occupies from 8 to 9 weeks.

Control.—A serious outbreak can only be checked by an organised campaign of lopping the dadaps within and just around the infested area and burning the loppings and by collecting and burning or burying deeply all the larvae and cocoons throughout the attacked area. The caterpillars and cocoons should be handled very cautiously on account of their irritating hairs, and the collecting coolies should be provided with rough forceps made of a piece of bent hoop iron.

Dadap is sometimes attacked by the rather slender hairy caterpillars of rather large pale-yellow moths (*Eupterote* spp.). The following is a brief description of *Eupterote geminata*, a pest of dadap. The hemispherical eggs are usually laid in masses so as to form a cylindrical tube encircling a twig or small branch. They are whitish to pale-yellow when freshly laid and may change to a pale-bluish colour before hatching:

Young to half-grown larva. Head orange-red, body with a broad pale-coloured stripe along the back and a dark stripe on each side, covered with rather long whitish hairs.

Full-grown larva. Nearly 3 inches long, pale-brown, with tufts of buff-coloured hairs on each segment. The younger caterpillars usually feed in large clusters on the leaves or they may be found in masses on the stems just before a moult. They may sometimes be seen crawling about the plants in long lines, usually in single file, with a leader, and each larva keeps closely in touch with the one in front of it. This habit of walking in processions is characteristic of the family *Eupterotidae* and has earned them the name of "processionary caterpillars". The older larvae usually scatter about over the plants while feeding. The larval period in some species is a long one, lasting about 10 weeks. The full-grown larvae burrow into the soil and pupate in earthen cells, the pupa being rather stout and dark brown to almost black. The pupal stage may last for 7 or 8 weeks. The moths lay their eggs soon after emergence and usually live only a few days. For further information on *Eupterote* larvae on dadap see Rutherford [16].

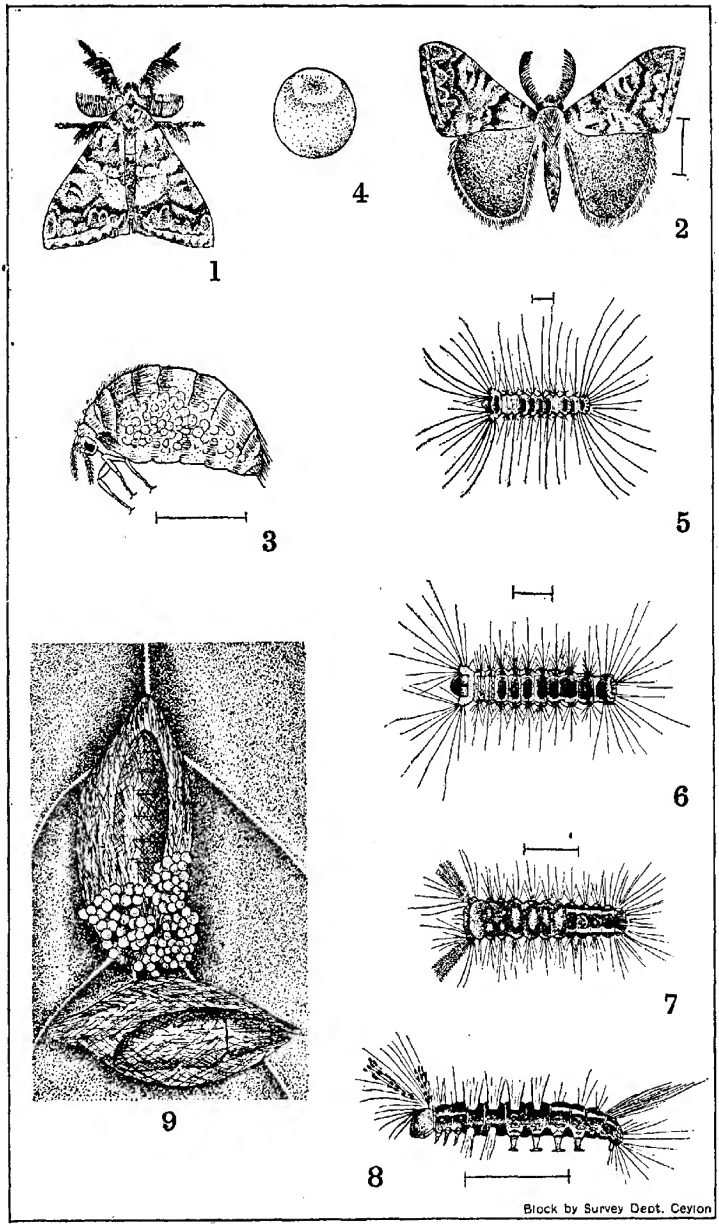

Plate III.—The Small Tussock Caterpillar (*Notolophus posticus*)

Fig. 1. Male moth, resting position, × 2.
Fig. 2. Male moth, wings spread, × 2.
Fig. 3. Female moth, side view, × 2.
Fig. 4. Egg, × 15.
Fig. 5. Larva, first stage, × 5.
Fig. 6. Larva, second stage, × 4.
Fig. 7. Larva, third stage, × 3.
Fig. 8. Larva, fourth stage, × 2.
Fig. 9. Portion of leaf, showing cocoons, and eggs, × 2.

Control.—Collect and destroy the egg-masses on the branches and the younger larvae when massed together on the leaves and stems. Fork the soil beneath the attacked plants to break up and expose the pupal cells.

Another caterpillar pest of dadap is the small tussock caterpillar (*Notolophus posticus*) which is widely distributed throughout the southern half of the Island at all elevations from sea level to over 6,000 feet. Besides being an occasional pest of dadap and *Albizzia* it is known to feed on a variety of other cultivated plants.

The following summary is taken from an article by De Alwis [1] who has studied the bionomics of this insect:

The male moth (Pl. III, Figs. 1 and 2) is an active winged insect with brownish wings mottled with black, while the female (Fig. 3) is a sluggish pale-brown creature with redimentary wings. It lays its shining white eggs in irregular masses usually on the cocoon from which it has emerged and a single moth may lay up to 600 eggs. The eggs hatch in from 7 to 11 days and the young larvae (Fig. 5) feed in masses on the younger leaves, sometimes completely hiding these with their bodies and masses of long hairs. The older larvae (Figs. 7 and 8) are quite conspicuous with their reddish heads and four short closely-set tufts or tussocks of yellowish or brownish hairs on the back; they also have a pencil of feathery hairs projecting forwards on each side of the head and a pair of long brownish tufts extending backwards from the anal segment. They are fully grown in about 16 to 20 days and spin their loosely woven cocoons between two or three leaves or on the twigs and usually cover them thinly with hairs from their bodies. The pale-brownish pupa is formed inside the cocoon and the moths emerge in about 7 to 9 days.

Control.—The caterpillars are normally controlled by parasites, the most important of which is the Tachinid fly (*Tricholyga sorbillans*). Small outbreaks can usually be checked by the collection and destruction of the cocoons with egg-masses on them and the clusters of young larvae.

Mention may also be made here of the dadap leaf-folder (*Agathodes ostentalis*), a description of which was given by De Alwis [2]. The brownish moth (Pl. IV, Figs. 1 and 2) has rather long olive-green forewings with a bright-pink band across the outer end. It lays its whitish scale-like eggs (Fig. 3.) mainly on the leaves and twigs. A single moth may lay nearly 400 eggs. These hatch in 5 to 6 days and the young larvae (Fig. 4) feed inside the undeveloped leaves, protecting themselves with

a fine web. The older larvae (Fig. 5) feed within a fold on older leaves, and are full grown in 14 to 18 days. The cocoons (Figs. 8 and 9) are often formed in a crevice in the bark or inside the empty tunnels of the dadap shoot-borer, and the slender brownish pupae (Figs. 6 and 7) are well protected by a closely woven covering. The pupal stage lasts from 15 to 19 days.

Control.—Usually no special control measures are necessary for this insect, since it is partially checked by the removal of the shoots injured by the shoot-borer.

Pests of Albizzia spp.—The most serious leaf-eating pests of *Albizzia* are the caterpillars of some three or four species of *Terias*, a group of small to medium-sized yellow butterflies with dark edges to their wings. For convenience these are usually mentioned under the name of *Terias silhetana*, but Ormiston [14] has pointed out that there are many variations in colour markings within the group, since wet and dry season forms of the various species are usually found together.

The butterflies fly in vast swarms from the jungles across cultivated areas and lay their eggs on the leaves of various species of *Albizzia*. The eggs are fusiform, or spindle-shaped, and pearly white at first, but turning to pale cream colour before hatching in 6 or 7 days. They are usually attached singly by one end to either the upper or lower surface of the leaves. The young larvae are whitish with pale-brown heads broader than the body. The older larvae are dull-green, with roughened bodies having a pale stripe along the sides and with either conspicuous black heads (*T. silhetana*) or green heads (*T. hecabe*). The caterpillars of *silhetana* are gregarious, while those of *hecabe* usually feed singly. They have a rapid development occupying only about 2 weeks. The pupae, or chrysalides, are somewhat boat-shaped, pointed at both ends, those of *silhetana* ranging from pale to dark-brown or almost black, while those of *hecabe* are usually pale to dark-green. The pupae are usually attached by the tail end and slung by a girdle from the leaves and bare leaf-ribs of their food plants or from any convenient object under or near the defoliated *Albizzia* plants or trees. The pupal stage lasts about one week. It will be seen that these insects undergo a rapid development, the whole life-cycle from the laying of eggs to the emergence of the butterflies occupying only about one month.

Control.—These pests are controlled to some extent by their natural enemies, mainly parasites, but usually the parasites do not get a start until after the *Albizzia* plants have been completely stripped over many acres. The attacked plants are

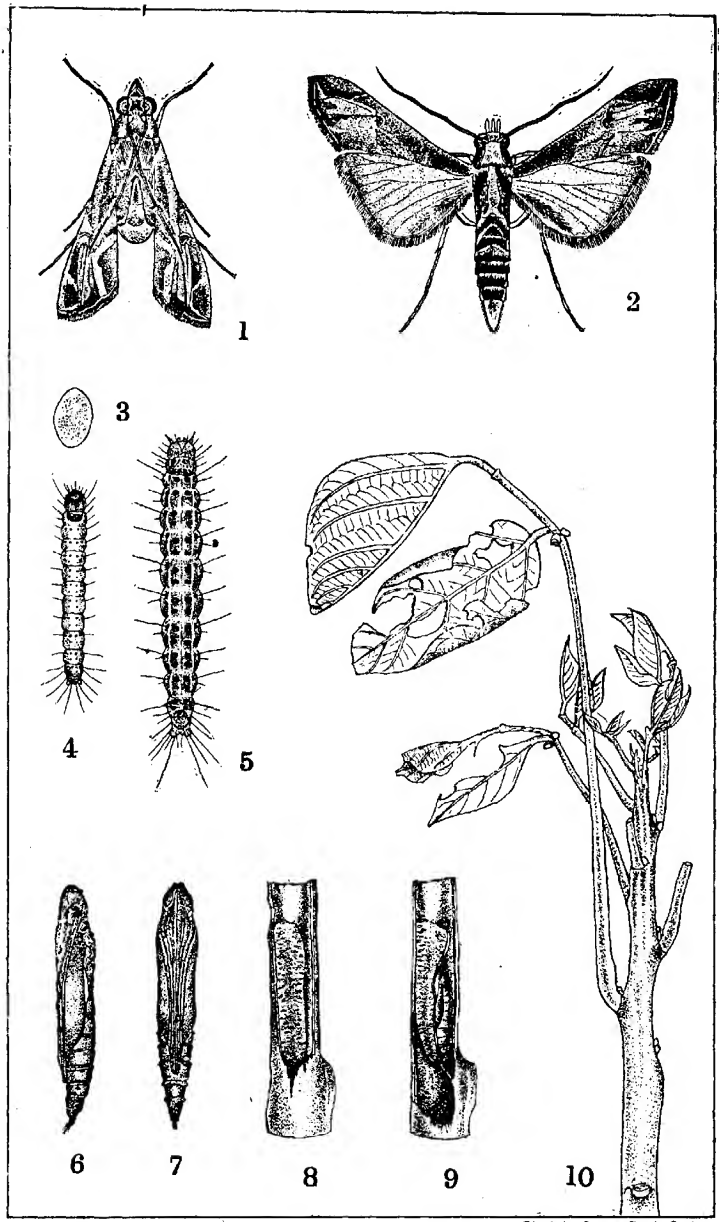

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Plate IV.—The Dadap Leaf-Folder (*Agathodes ostentalis* Hubn.)

Fig. 1. Moth, resting position, with tip of abdomen turned up, × 2.
Fig. 2. Moth, wings spread, × 2.
Fig. 3. Egg, × 10.
Fig. 4. First stage caterpillar, × 5.
Fig. 5. Full grown caterpillar, × 2.
Fig. 6. Pupa, lateral view, × 2.
Fig. 7. Pupa, ventral view, × 2.
Fig. 8. Portion of shoot showing cocoon of *Agathodes* in old tunnel of *Terastia*, nat. size.
Fig. 9. Lateral view of fig. 8, showing pupa inside cocoon, nat. size.
Fig. 10. Showing young leaves folded and partially eaten, nat. size.

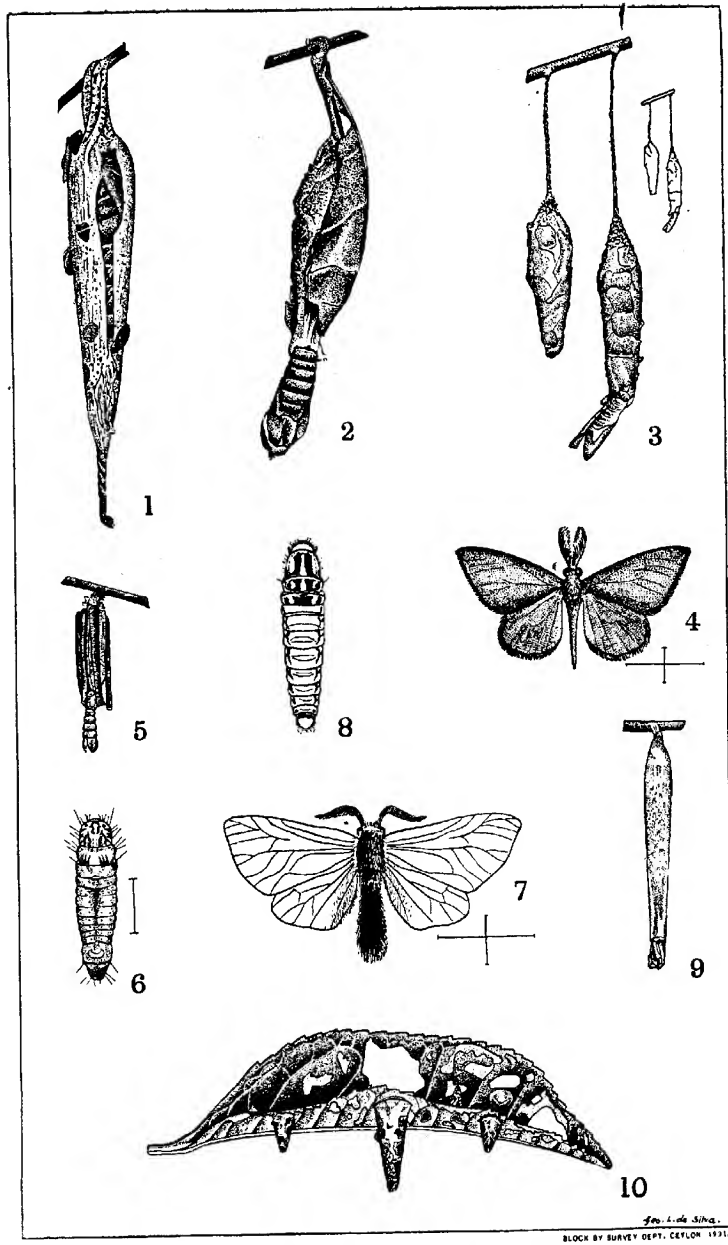

Plate V.—Some Bagworm Pests of *Albizzia*.

Fig. 1. *Clania variegata*, case slit to show pupa inside.

Fig. 2. *Clania variegata* leaf-covered case, with empty male pupal skin protruding.

Fig. 3. *Acanthopsyche* sp., two cases × 3, one with empty male pupal skin protruding; nat. size at side.

Fig. 4. *Acanthopsyche* sp; type of dark coloured male moth, × 3.

Fig. 5. *Chalia doubledayi*, with empty male pupal skin, nat. size.

Fig. 6. *Chalia doubledayi*, larva removed from case, × 3.

Fig. 7. *Chalia doubledayi*, type of clear winged male moth, × 3.

Fig. 8. *Clania* spp., larva removed from case, nat. size.

Fig. 9. *Psyche vitrea*, case with empty male pupal skin, nat. size.

Fig 10. *Psyche albipes*, feeding on tea leaf, nat. size.

sometimes seriously injured by successive defoliations and in such cases lopping may result in a die-back of the branches. The pupae can sometimes be collected in large numbers and destroyed. On young *Albizzia* plants the young caterpillars can be killed by spraying them with a solution of soft soap and water at the rate 1 lb. to 6 gallons.

Another caterpillar (*Macaria pluviata*) has recently been recorded by Light [13] as a pest of *Albizzia* seedlings in nurseries. This is one of the Geometrids or "loopers" and Light found that while the larvae feed in preference on the tender leaves they may strip the plants completely. He also noted that the continued destruction of the growing points may result in the death of the young plants or cause a serious set-back. Details of the habits, life-history and control measures are given in the article.

Control.—Spraying with Paris Green at the rate of 1 lb. to 50 gallons of water is recommended. This works out at about 1 oz. to 3 gallons, which seems rather a strong dose for young plants. As an alternative to spraying, dusting with Paris Green diluted with four or five of its weight of sifted lime, is recommended. Probably a dilution of 1 in 8 would be safer for young plants and is quite effective at this strength against most leaf-eating insects.

Bagworms on Albizzia.—There is evidence that various species of bagworms and faggotworms, formerly regarded as pests of tea and rubber only among crops of economic value, are now becoming prevalent on *Albizzia*, particularly at lower elevations. These insects are the caterpillars of several different species of moths belonging to the family Psychidae, and they all have a similar characteristic development, in that, with the exception of the active-winged male moths, the larval, pupal, and female moth stages are spent within cases made by the larvae. These cases are constructed of finely woven silk to form a tough tubular covering which in some species is adorned with the pieces of twigs, leaves, etc. Some of these insects are illustrated in Plate V. Most species consistently employ their own characteristic covering, but *Clania variegata* sometimes attaches only a few small pieces of twigs or leaves to its case (Fig. 1), while at other times the case may be completely hidden by large pieces of leaf (Fig. 2).

The female insects remain inside their cases after struggling out of their pupal cases and the eggs are laid also inside the cases. The young caterpillars on hatching find their way out and each soon makes its individual case, which is gradually enlarged with the growth of the inmate. A caterpillar when

feeding may move about dragging its case along or it may attach its case loosely to a leaf, exposing only the head and front part of the body; these segments have a thicker and darker skin than the hinder portion of the body which always remains inside the case and is soft and whitish (Fig. 8.). The full-grown larva before pupating attaches its case very strongly to a leaf or twig and seals up the mouth of the tube with silk. The actual pupation has not been observed, but Green [3] states that the larva, when ready to pupate, turns round inside the case with its head towards the hinder opening of the tube and changes into a chrysalis in this position. If the insect happens to be a male it emerges later as a moth, usually of a brownish colour (Fig. 4) but sometimes with colourless transparent wings (Fig. 7). The male moth on emerging leaves its empty pupal skin protruding from the case (Figs. 2, 3 and 5). As indicated, the female does not leave its case, but is fertilised therein by the male which has a very flexible and extensile abdomen and organ.

Recent records by Light [12] and by the writer indicate that *Albizzia* may be attacked by the following species of bag worms and faggotworms: *Clania variegata* (Figs. 1 and 2), *Psyche vitrea* (Fig. 9), *Psyche albipes* (Fig. 10), *Acanthopsyche* sp. (Figs. 3 and 4), and *Chalia doubledayi* (Figs. 5, 6 and 7). In the case of a serious outbreak the *Albizzia* plants may be completely stripped and sometimes even the bark is gnawed away in patches, particularly by *Psyche albipes* and *Chalia doubledayi*.

Control.—Since the females are wingless and do not leave their cases it follows that these pests can only spread in the larval stage. It is probable that the young larvae may be blown by the wind or they attach themselves to coolies' clothing and be carried to uninfested areas. All cases found attached to plants should be removed periodically and destroyed, especially on estates which have had attacks of these pests, since some of these cases may contain egg-laying females about to start new centres of infestation.

In the early stage of an attack the insects are usually confined to small patches of plants and are probably the progeny of a few females; it is at this stage that a serious increase can be checked by handpicking the cases and destroying them. These pests are normally controlled by parasites, but once an outbreak has got out of hand the parasites are unable to resume control until a vast amount of damage has been done.

Pests of Crotalaria spp.—The cultivated species of *Crotalaria* may sometimes be severely injured by the attacks of the caterpillars of at least two species of *Argina* moths, namely

Argina argus and *Argina syringa*. The conspicuously coloured moths of both species have a wing-spread of over two inches, the front wings of *argus* being brownish pink with numerous irregular white-ringed black spots, while the hind wings are salmon pink with ringless black spots; the *syringa* moths are very similar in appearance to those of *argus* except that the colours are darker.

The newly-hatched hairy caterpillars of both species are gregarious, feeding in masses on the tender shoots of various species of *Crotalaria*, both wild and cultivated. The full-grown larvae of *argus* are about 2 inches long, black, with a line of white spots along the middle of the back, while those of *syringa* are dull greenish-gray, with transverse series of narrow black bands, three on each segment of the body. Both species of larvae are hairy and very conspicuous on the plants. They usually feed on the leaves and flowers and sometimes bore into the pods in order to eat the seeds. They are also capable of doing serious injury to the stems of the plants by gnawing the bark and sometimes girdling the stem so that the plants wither and die back or break off at the point of injury. The pupa or chrysalis is reddish-brown, spotted and banded with black and is usually slung in a thin silken web and attached to the plant.

Life-History.—The eggs are laid in clusters on the young shoots, and hatch in about 4 days. The larval period of *argus* in captivity ranges from 18 to 23 days and the pupal period averages about 10 days. The moths may live for nearly a month in captivity during which time they may lay from about 250 to well over 1,000 eggs.

Control.—The caterpillars can be collected and destroyed, especially in the young stage when they are massed together on the shoots and leaves. The pupae in their cocoons on the plants also lend themselves to easy control by hand-picking. It is essential to control the pests in its early stages before any serious permanent injury can be done to the plants.

The Indigofera leaf-webber (*Dichomeris ianthes*).—The various species of *Indigofera* are sometimes attacked by a small greenish caterpillar which webs the leaves together and feeds within the webbed masses of leaves. The cocoons are formed within the masses of shrivelled leaves on the plants or within individual fallen leaves. The moth is a small grayish brown insect.

Control.—The tipping of the plants and burning of the tippings with any eggs, larvae and cocoons is probably the only practicable method of control for this pest on *Indigofera*

interplanted with tea. *Indigofera* in nursery beds or among other main crops can be sprayed or sprinkled with the Paris Green mixture.

Pests of tea and green manures.—Mention may be made here of some of the more important leaf-eating insects formerly regarded mainly as tea pests which have become increasingly prevalent within recent years on various green manure crops. The recent records of several species of bagworms which are becoming addicted to *Albizzia* have already been indicated but there are several other leaf-eating insects to which attention should be called as potential pests of green manures.

Tea tortrix (*Homona coffearia*) is known to feed on the commoner species of *Acacia*, on dadap (*Erythrina* spp.) on *Crotalaria* spp. and on *Grevillea*.

There are a few species of leaf-eating weevils which have been minor pests of tea for many years and some of them are known to feed on green manures; and it is probable that they are extending their range of food plants among these crops. The gray weevil (*Myllocerus curvicornis*), a common pest of dadaps, also attacks *Acacia* and *Albizzia* and has been recorded by Light [11] on *Gliricidia*. The bronze weevil (*Astycus immunis*) is known to feed on *Acacia*, while a green variety (*bilineatus*) of this species has been recorded by Light [11] on dadap.

Very little is known about the life-histories of these weevils. The eggs are laid in the soil and the grubs probably feed on the roots of plants, while the weevils emerge from the soil after pupation. They attack the young shoots and nibble the edges of the older leaves of their host plants.

BORERS

The dadap shoot-borer (*Terastia meticulosalis*) probably occurs in most districts where dadap is grown as a green manure crop and its damage is well known. The bionomics of this pest have been studied by De Alwis [2] and the different stages of this insect are shown in Plate VI. The following is a brief summary of our information on this boring caterpillar.

The grayish-brown moth usually rests in the position shown in Figures 1 and 2, the rather narrow forewings not completely covering the hindwings and the abdomen turned up at the tip. The somewhat oval, soft and whitish eggs are laid singly on the bases of the tender leaf-stalk (Figs. 9b and 10) and hatch in about a week. The larva (Fig. 4) on hatching first of all bores

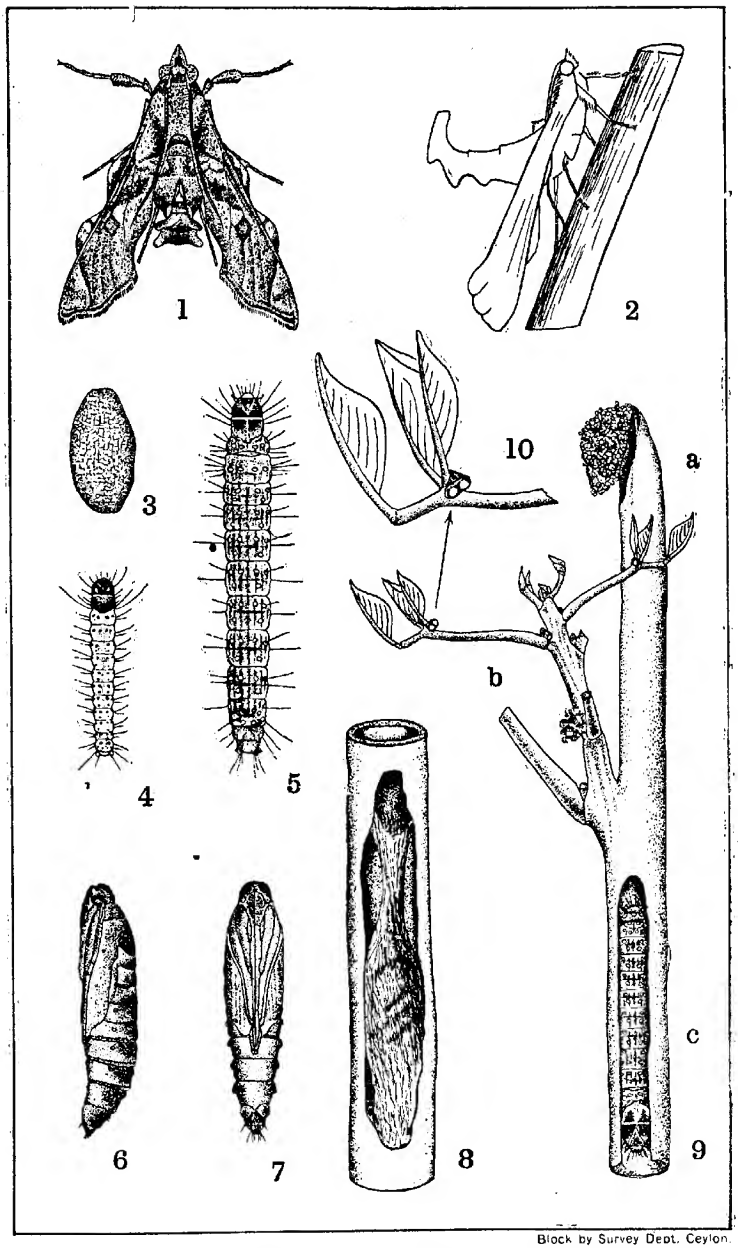

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Plate VI.—The Dadap Stem-borer (*Terastia meticulosalis* Guen.)

Fig. 1. Moth, resting position, with tip of abdomen turned up, × 2.
Fig. 2. Moth, resting position, side view, × 2.
Fig. 3. Egg, × 20.
Fig. 4. First stage caterpillar, × 6.
Fig. 5. Full grown caterpillar, × 2.
Fig. 6. Pupa, lateral view, × 2.
Fig. 7. Pupa, ventral view, × 2.
Fig. 8. Section of hollow shoot with portion removed to show cocoon inside, × 2.
Fig. 9. Showing damage by borer, × 2.
(a) Primary shoot killed back,
(b) Secondary shoot being attacked,
(c) Caterpillar in tunnel.
Fig. 10. Portion of 9b, enlarged to show two whitish eggs (indicated by arrow).

into an immature leaf and in about 2 days it enters a young shoot near the tip and tunnels down the centre gradually causing the shoot to die back. A mass of excrement or frass usually protrudes from the tip of an attacked shoot, (Fig. 9a). The larva is full-grown (Fig. 5) in about a month and spins its cocoon inside the hollow decaying shoot. The pupal stage occupies about 2 to 2½ weeks. The dying-back of the first shoots usually causes the plants to throw out several side shoots resulting in the production of more leaf, but sometimes these secondary shoots may also be attacked.

Control.—This pest can usually be controlled by the ordinary periodical lopping, but individual attacked shoots should be removed and burnt at any time that the borer threatens to increase; their destruction will kill either the larva or pupa inside.

The bark-eating borer (*Arbela quadrinotata*) is sometimes a pest of dadap and *Albizzia* and is known to attack tea and cacao. The eggs are probably laid in crevices in the bark and the larva makes a tunnel in the stem or at a fork within which it lives, coming out to feed on the bark under the protection of a silken gallery covered with frass.

Control.—The borers can sometimes be killed within their tunnels on young or low-growing plants by probing with a stout pointed wire; the holes are sometimes plugged with tar. During an outbreak of this pest on *Albizzia* in 1926 Holland [4] found that it could be effectively controlled by stopping the holes with "Plascom" and liquid fuel. This melted in the sun, but the caterpillars, while attempting to emerge, were caught in the sticky material and almost all killed.

Termites (*Calotermes* spp.).—The various species of *Calotermes* now so well-known as serious and widespread pests of tea have been found within the last few years to attack such green manure plants as *Acacia*, *Albizzia*, *Erythrina*, and *Grevillea*. They have also been found in other economic crops, in timber and ornamental trees and in various jungle trees.

As in the case of tea the termites may gain entry through wounds and snags and gradually bore into the sound heartwood causing further die-back of the branches and stems and eventually the death of the plants. Recent observations indicate that *Calotermes* may gain entry into tea and green manure plants through the roots from old infested jungle stumps and roots. Dadap (*Erythrina* spp.) is known to be attacked by *Calotermes* (*Neotermes*) *militaris* and *Calotermes* (*Neotermes*) *greeni*, *Albizzia* by *C.* (*N*) *militaris*, and *C.* (*Glyptotermes*) *jepsoni*,

and *Acacia* by *C.* (*N*) *militaris*. *Grevillea* is attacked by *C.* (*N*) *militaris*, *C.* (*N*) *greeni*, and *C.* (*Glyptotermes*) *dilatatus*. For full information on these pests the work of Jepson [8, 9, 10] should be consulted.

Pod-boring insects.—The seed-pods of boga medeloa (*Tephrosia candida*), *Indigofera* spp. and occasionally *Crotalaria* spp. are attacked by the grubs of a small brownish beetle (*Araecerus fasciculatus*), commonly known as the *Tephrosia* beetle. This beetle sometimes causes serious losses in the seed crop of boga.

The eggs are laid in the seams of half-ripe pods in small holes previously gnawed by the beetles, a single egg to a hole usually near a seed. The eggs hatch in about a week and the grubs bore into the adjoining seeds, consuming these. The grubs are full-grown in about one month and pupate inside the pods. The pupal stage lasts about one week, and the beetles may remain inside the pods for about another week or so before gnawing holes in the side for emergence, which may take place before the pods open.

Control.—Where *Tephrosia* is grown as a green manure among a main crop such as tea or rubber, this pest is usually controlled by the periodical loppings before the flowering and fruiting of the plants. This removal of the flowers and pods in green manure areas of *Tephrosia* is essential if there are any areas of this plant being grown for seed anywhere near the interplanted *Tephrosia*, since it has been found in Java that the beetles can fly long distances up to half-a-mile and that *Tephrosia* can be infested from green manure areas of *Tephrosia* and from wild pod-bearing leguminous plants.

Petch [15] gives a review in *The Tea Quarterly* of an article describing the methods of combating the *Tephrosia* weevil in Java. These measures include the systematic removal of the first nearly ripe pods by special collecting gangs. The destruction of these pods prevent the further development of the infesting grubs and pupae into beetles which would otherwise emerge and attack the later crop of pods.

The three or four species of small pod-boring caterpillars which attack the seeds of boga medeloa can also be controlled by the above methods.

SUCKING INSECTS

Among the sucking insects which are known to feed on green manure crops may be mentioned a few of the larger plant-sucking bugs and some of the smaller insects, such as aphids, scale insects, and mealy-bugs.

Cyclopelta siccifolia is a Pentatomid bug, a little more than ½ inch long, oval in shape and of a very dark brownish-black colour, except the membraneous portions of the front wings which are of a lighter brown colour. The nymphs, or younger bugs are lighter in colour. Both adults and nymphs have the habit of feeding in large masses on the twigs and branches of dadap and on *Indigofera* spp., sometimes causing the injured portions to wither. The insects have a strong odour and when disturbed they may sometimes eject a liquid which produce a smarting sensation to the skin. Adult bugs have been kept in captivity for several months on end at various times, but never laid any eggs. Rutherford [16] noted that the eggs are placed in longitudinal rows on the branches.

Control.—Since the bugs usually feed in clusters, it is a simple matter to brush them off into a tin of water with a little kerosene on the top.

The smaller Membracid bugs (*Otinotus* spp.) are occasionally very numerous on the young shoots of dadap, while closely related bugs belonging to the genera *Leptocentrus* and *Gargara* occur on *Indigofera*, *Tephrosia*, and *Crotalaria*. These bugs are remarkable by reason of their horn-like appendages of various shapes giving them a most grotesque appearance. Both adults and nymphs usually cluster together in small groups and when disturbed they exhibit remarkable jumping powers.

The eggs are laid in slits made in the bark by the females with their saw-like ovipositors. The combined feeding of numbers of these bugs and the egg-slits sometimes injure the young twigs. These minor pests are usually checked by egg-parasites.

Turning to the smaller and less active sucking insects we find that the tender shoots of *Gliricidia* are sometimes heavily infested with aphids (*Aphis gossypii*), which cause a distortion and withering of the young leaves. These insects are usually controlled by lady-bird beetles and their larvae and by syrphid fly maggots, but if they become a pest they can be sprayed with the soap and water solution 1 in 8.

Of the scale insects attacking green manures, probably the only one of any serious importance is the boga scale *Ceroplastodes cajani*) which sometimes covers patches of boga with a whitish incrustation. Unless the infested shoots and branches are lopped the scales spread down the stems and the plants may die back or be seriously weakened. In cases where scale-infested boga plants die out entirely there is usually some evidence of root disease as well. This scale is often controlled by parasites. For other control measures see Insecticides.

Boga shoots are sometimes attacked by mealy-bugs (*Pseudococcus virgatus* and *Pseudococcus citri*), but these are usually of minor importance as compared with the scale.

Albizzia and *Gliricidia* are also attacked by *P. virgatus* and *P. citri* is found on dadap and *Gliricidia*.

The roots of green manure plants are sometimes infested with mealy-bugs, but there is no evidence to show that they cause any serious injury. Light [12] has recorded *Pseudococcus maritimus* on the roots of *Albizzia lopantha*.

The recent extension of the areas under *Gliricidia* as a green manure for tea has been followed by the appearance of green bug (*Coccus viridis*) on this plant in districts where green bug has not been known previously. This scale insect usually gets on to the tea from the *Gliricidia* and under favourable conditions it may succeed in establishing itself there.

The most conspicuous feature of attacks of sucking insects, such as scales, mealy-bugs, and aphids is the blackened appearance of the leaves popularly termed "black blight" or "black bug". This unsightly condition of the plants is to "sooty mould" a non-parasitic fungus which develops wherever the secretions of the insects happen to fall. It usually forms a superficial film on the upper surfaces of the leaves and sometimes covers the twigs and branches, but is of no special importance, except that it often calls attention to the presence of the pests. It gradually disappears after the insects are killed.

HIGH CULTIVATION

It is now becoming generally recognised that green manure plants should receive similar care and attention as regards cultivation and manuring as do the main crops among which they are grown. High cultivation not only enables them to recover from the attacks of the numerous leaf-eating pests mentioned above and from the frequent loppings which they have to undergo, but helps them to maintain their vigour in spite of attacks by sucking insects. Normally vigorous plants growing under suitable conditions can usually maintain an ordinary infestation of scale insects or mealy-bugs without any apparent loss of vitality and for some reason or other the scales do not increase unduly. On the other hand, plants whose vitality has been impaired by attacks of leaf-eating or boring insects or by diseases or by unsuitable soil and climatic conditions are usually unable to cope with the additional drain—and it is literally a drain on their vigour caused by a scale or mealy-bug attack. The scales or mealy-bugs usually increase rapidly, and

unless the pest is temporarily checked by parasites or by artificial measures, such as loppings or spraying, the plants seem unable to throw off the attack in spite of high cultivation. Therefore, it is recommended that if scales tend to persist in any given area, then the infested branches should be lopped and burnt or the plants should be sprayed with a contact insecticide, in order to get rid of the pest and give the plants a chance to regain their lost vitality and withstand any subsequent renewal of the attack. If high cultivation is maintained and provided that the plants are not naturally weak they should remain free from a recurrence of serious scale attacks.

INSECTICIDAL MEASURES OF CONTROL

It will have been observed that practically the only measures which have been recommended above for the control of insect pests of green manures are collection and destruction of leaf-eating pests and lopping and burning the infested portions of the plants for sucking insects, such as scales and mealy-bugs. As a general rule these are measures which can be carried out at a reasonable cost as part of the estate routine by the ordinary estate coolies and they are usually effective against most outbreaks if applied in the early stages of an attack.

There are, however, alternative measures of control for leaf-eating pests and one of these in the application of a stomach poison, usually an arsenical, to the leaves of the infested plants; these insecticides are usually applicable only to low-growing plants unless high-powered spraying machines can be used. Those green manure plants which are grown primarily for their loppings, as opposed to those which are grown mainly for shade, can usually be kept down to a reasonable height and therefore accessible to the spray or dust from ordinary spraying machine or powder gun, so that spraying or dusting with an arsenical stomach poison should be quite practicable from the purely mechanical operation of getting the poison on to the plants.

Since, however, green manure plants are usually interplanted with a main crop for the benefits they confer indirectly on the main crop, it would be practically impossible to prevent any insect poison used on the green manure crop from also getting on to a low-growing main crop such as tea. Since the leaves of tea are made into a product for human consumption it follows that the use of arsenicals on any green manure interplanted with tea is out of the question, so far as we know at present.

Experiments have been made by this Department with a few non-arsenical poisons, such as lead chromate and sodium silicofluoride, on such tea pests as tortrix and nettle grubs, but so far these have not given satisfactory results. Recent experiments against nettle grubs with various contact insecticides, such as usually recommended for sucking insects, have indicated that some of these give promising results against young to half-grown larvae and it is possible that as the result of further experiments, some of these may be useful against the younger stages of some of our green manure caterpillars. The cost of most of these contact sprays is at present rather high for use on large areas under estate conditions and the cost of materials and application are among the limiting factors in any large scale spraying operations.

While the use of arsenicals is at present not advisable on green manure crops interplanted with tea, there seems to be no objection, beyond that of cost, to their application to green manures of moderate height and to cover crops interplanted among such crops as rubber, coconuts, cacao, etc. They can also be used on young green manure plants in nurseries or on any of these plants grown in separate areas for seed. For this purpose, the Paris Green formula given below will be found suitable for practically all leaf-eating insect pests on green manure crops. As an alternative a fairly cheap contact insecticide for young caterpillars and young locusts is a soft soap solution at the rate of 1 lb. of soap in 6 to 8 gallons of water, depending on the age of the pest. Kerosene emulsion is a useful contact insecticide against the hardier sucking insects, while the soft soap solution can be used against aphids.

FORMULAE OF INSECTICIDES

Stomach poisons for leaf-eating insects, such as caterpillars and beetles.

Paris Green Spray Formula:

Paris Green	½ oz. or 3 large level teaspoonfuls.
Quick lime	2 oz. or a handful.
Water	4 gallons, or a kerosene tin full.

Slake the quick lime, or fresh stone lime, in some of the water; mix the Paris Green in a little of the water to make a thin paste; add the slaked lime to the remainder of the water in the tin and stir in the Paris Green paste thoroughly.

The above ingredients should not be mixed until just before they are needed for application nor should more of the mixture be made up than is likely to be used the same day. The

mixture should be kept stirred thoroughly while in use so as to prevent the Paris Green settling to the bottom. The addition of quick lime is intended to neutralise any free arsenic which might burn the foliage. The above formula is suitable for use on tender foliage against young caterpillars; for older caterpillars and for beetles use double the quantity of Paris Green and lime for the same amount of water. Apply the liquid so as to wet both sides of the leaves thoroughly using a machine giving a fine misty spray.

If no suitable spraying machine or syringe is available then the mixture can be distributed in wide-mouthed earthenware chatties to coolies supplied with a bunch of leafy twigs (such as *Grevillea*) with which the mixture can be sprinkled on to the plants. Stir the mixture thoroughly while pouring into the chatties so that each vessel gets an even distribution of the portion. This method of application is more wasteful than spraying but is useful in an emergency.

Paris Green Dust Formula.—Paris Green can be mixed thoroughly with any fine dust, such as finely sifted slaked lime, wood ashes, flour, etc., in the proportion of 1 part of the poison to 8 parts *by weight* of the dust for large caterpillars and for beetles, and 1 to 16 or even 1 to 32 for small larvae on tender foliage.

Contact insecticides for sucking insects, e.g., scales, mealy-bugs, and aphids.

Kerosene Emulsion Formula:

Any good bar soap	...	½ lb.
Soft water	...	1 gallon.
Kerosene	...	2 gallons.

Shave the soap into fine flakes and dissolve it in hot water; then add the kerosene and churn the mixture thoroughly by drawing it up into a garden syringe and forcing it back into the vessel, such as a kerosene tin. Keep on churning until the mixture begins to thicken; the emulsion is completed when the creamy mass begins to pass through the pump with difficulty. If the water is fairly soft, as it usually is in most parts of the Island except in the Jaffna district, the emulsion should be formed fairly soon. Hard water can be softened by adding a little borax or soda. Unless a proper emulsion is obtained there will be a residue of free oil which would burn the leaves. The resulting emulsion is the stock solution and for application mix 1 part of the stock with 9 or 10 parts of water for soft bodied insects, such as aphids, soft scales, and mealy-bugs. For

tougher scales, such as the boga scale, the lantana bug, and other scales which are well protected, use 1 part of the stock to 5 or 6 parts of water, although tender foliage may sometimes be injured at this strength. Apply the liquid so as to wet the insects on the plants thoroughly, first examining them to see where most of the insects are feeding.

Soaps.—Quite a useful contact insecticide can be obtained by dissolving any good bar soap in water at the rate of 1 lb. of soap to 6 or 8 gallons of water. Soft soaps or ready made resin-fish-oil soap are usually more effective and more adhesive than hard soaps at the same strength, but they are not always available in an emergency. This soap solution is effective not only against aphids, soft scales, but has recently been found useful against young to half-grown caterpillars and young locusts.

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